report

CR-191

Tactical Electrooptical Effectiveness Model

Phase II

Volume I

By:

Ralph Zirkind
Richard E. Forrester

Prepared for

U.S. Army, ERADCOM
Night Vision Laboratory
Fort Belvoir, Virginia
Contract No. DAAKO2–74–C–0366

June 1977

GENERAL RESEARCH CORPORATION
WESTGATE RESEARCH PARK, McLEAN, VIRGINIA 22101

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The report covers the recently completed effort in an on-going program of land-combat search and its simulation. It involves the incorporation of a tactical electrooptical effectiveness model into the combat simulation model, CARMONETTE. Volume I identifies the modifications in CARMONETTE rule structure that were necessary for this incorporation.

Three cases of small unit action were simulated with the

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resulting model employing both thermal and image intensifier devices in nighttime scenarios. Volume II reports their results.

FOREWORD

The authors wish to acknowledge the assistance provided by Mr. J. E. Shepherd who ably assisted in the CARMONETTE reprogramming effort.

Also, the authors wish to acknowledge the fruitful discussions with the staff of the Night Vision Laboratory, particularly Dr. W. Lawson, J. Ho and A. Linz, the contract monitor.

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ABSTRACT

This report addresses the recently completed effort in an on-going program of land-combat search and its simulation being performed by GRC under contract to the US Army Night Vision Laboratory at Ft. Belvoir, Virginia. The principal investigator is Dr. Ralph Zirkind who has developed a search model that has been incorporated into the combat simulation, CARMONETTE. Three cases of small unit action were simulated with the resulting model, employing both thermal and image intensifier devices in nighttime scenarios.

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1. INTRODUCTION

1.1 BACKGROUND

This research program was initiated in 1974 and had as an overall objective the development of a tactical electrooptical effectiveness model where effectiveness was to be measured in the combat simulation model, CARMONETTE. The first phase efforts are reported in GRC report OAD-CR-121.

As a first step in Phase 1, a critical literature review (by B. Goldberg) and analysis (by R. Zirkind) of the psychovisual literature with special emphasis on detection, were performed to establish the relative significance of the dependent variables in the search process. On the basis of the analysis a first generation algorithm (a search model) was derived by Dr. Zirkind which would permit the computation of the cumulative probability of detection as a function of search time. The dependent variables in the search process were: (1) target size, (2) search area, (3) sensor field-of-view, (4) contrast, and (5) clutter. For the unaided eye and aids operating in the visible region, the contrast entered as a square term whereas for thermal viewing systems operating at LWIR wavelengths the contrast term entered as a first power term. The analytical results were compared with field results and found to give encouraging results.

Finally, the search model was applied to a tank/antitank simulated night duel, at the company level, to evaluate the effectiveness of FLIRs on the battlefield. The results clearly demonstrated the significant improvement in target acquisition capability provided by the FLIR over passive image intensifiers and the corresponding improvement in combat effectiveness.

The simulation model that was employed for the search model evaluation in Phase I was CARMONETTE. Its use in such an evaluation was made possible only by massive effort to convert the search model parameters into appropriate input to the CARMONETTE model as it was then programmed. To this end, probabilities of detection (given intervisibility) were calculated by Dr. Zirkind under various parametric conditions and these were converted to forms acceptable as CARMONETTE input by R. E. Forrester. With a slight modification to the CARMONETTE preprocessor program performed by R. G. Williams, these new inputs were used to run the two cases of simulated night combat under varying light levels.

The results of the Phase I study were encouraging enough to plan under Phase II for the actual programmed inclusion of the search model into CARMONETTE and to refine the search model itself. It should be noted that a 2nd generation search model was developed, including clutter, prior to the end of Phase I.

Subsequently, Dr. Zirkind developed independently a 3rd generation search/detection model and a recognition model which was reported to the NVL and again, reported in the November/December 1975 Monthly Management Report. These algorithms were examined and validated by NVL within their range of applicability. Its inclusion under Phase II as an integral part of the CARMONETTE simulation would necessitate additional modifications to the simulation so that the parameters necessary to the search model would be available as needed. These parameters included such things as a definition of the sector of responsibility for each combat unit, the amount of unmasked land in his sector that was visible to him (available for search), calculations of intrinsic contrast and atmospheric attenuation of that contrast, and a drastic modification of the comparison of random number with probability of target acquisition to determine when the latter occurred.

It was decided that these modifications were necessary if a realistic inclusion of the Zirkind search model were to be made.

During the summer and fall of 1976, the programming changes to the CARMONETTE model were made and debugged. Combat simulations were then performed as further tests of the newly-combined model. Three cases of nighttime combat resulted employing Image Intensifier and Thermal devices in low-echelon combat.

The evolving search model simulation was gaining credibility and included many of the properties necessary to a good simulation of the search process in a combat setting. It included a timely description of the area of search for each combatant with that area changing as a function of knowledge gained. It handled cumulative probabilities of detection and recognition as a function of time over stretches of intervisibility between opposing combatants (incorporating changing parameters automatically). It addressed the clutter problem in a simplified form. And at the center of each calculation was the Zirkind search model fully incorporated for thermal and image intensifier devices.

1.2 PHASE II

The Phase II effort included the incorporation of the Zirkind 3rd generation search/detection model into CARMONETTE with the associated logic modifications necessary to that inclusion. It also involved the application of the resulting model to a set of nighttime scenarios as a final check-out procedure.

Phase II documentation consists of two volumes. Volume I contains the Zirkind 3rd generation search/detection model and its incorporation in the CARMONETTE rule structure*. Volume II contains the report of night combat simulations employing the new modified CARMONETTE logic.

The Volume I report is given at two levels of detail. First, an overview presents the nature of the CARMONETTE modifications. Included in this overview is a brief description of the CARMONETTE model as it existed before the search model inclusion, an identification of the search model itself, and a general description of its incorporation into CARMONETTE. The overview is oriented toward the reader with only a general knowledge of simulation methods.

The second level of detail in Volume I is oriented toward the CARMONETTE user and demands as prerequisite a fair grasp of the overall

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* For a complete description of the CARMONETTE model, one is referred to "CARMONETTE" in three volumes, November 1974, prepared by GRC-OAD under Contract DAAG39-74-C-0128 for US Army Combat Analysis Agency.

CARMONETTE rule structure (before modification). It delineates the CARMONETTE logic modifications, first in terms of the parameters involved and then in terms of the subroutines that were modified.

2. OVERVIEW

This section presents the framework for incorporating the Zirkind search model into the CARMONETTE logic. A brief description of the CARMONETTE model is presenced with an emphasis on its surveillance structure. The search model formulated by Dr. Zirkind is then presented. Finally, the incorporation of that search model, along with related modifications, is discussed.

2.1 THE CARMONETTE SIMULATION

2.1.1 General

CARMONETTE is a fully computerized Monte Carlo mathematical simulation of small unit ground combat. It is a time-sequenced critical-event war game that simulates the activities of movement, target acquisition, communications, and weapon employment by infantrymen and various vehicles, including tanks, armored personnel carriers, and helicopters, and a wide variety of weapons. Resolution can be at the level of the individual soldier or vehicle, or at squad or platoon level. Up to a reinforced-battalion-size force can be represented on each side.

CARMONETTE plays on a terrain simulation of 3780 grid squares (60 by 63). The arrangement of the grid squares is fixed, but the grid size may range from 10 m to 250 m or larger depending on the size and type of units being simulated. Each grid square is described in terms of average elevation, available cover and concealment, cross-country and road trafficability, and height of vegetation.

CARMONETTE runs from a predetermined scenario and each unit is required to have explicit orders for its actions. Certain contingency type orders are available under which the actions of a unit will depend on its knowledge of and the actions of enemy or other friendly units. Battles as long as 60 to 90 minutes can be simulated.

2.1.2 Surveillance

The Surveillance Routine is the portion of the Battle Model in which target detections are determined. A surveillance cycle (also called scan time) is input for each sensor and this time determines the frequency at which a unit conducts surveillance with that sensor. When the surveillance clock for each sensor device becomes the lowest clock of the unit's list of ordered events, that unit's master clock is set for surveillance with that device. At the beginning of the game, the initial setting of all the surveillance clocks of all units is set to random times so that the units in the game will conduct surveillance at different times.

When a unit is conducting surveillance, the computer processes each opposing unit for consideration of possible acquisition. If the target passes the following test:

- It is not on the known dead list
- It is in line of sight (i.e., intervisible with the sensor)
- It is not already acquired
- It is within sensor range

a probability of improving the target location information is calculated and a random number is drawn to determine success or failure.

After a target is found, then on the subsequent entry into the Surveillance Routine, a probability of "loss" is calculated and a random number is drawn to determine whether this target has been lost (even though it remains intervisible).

Four levels of states of information concerning target location are employed in CARMONETTE. They are:

1) No information
2) Nearest square
3) Erroneous pinpoint
4) Pinpoint

The operational definitions of these levels allow aimed fire at level 4 with direct fire weapon performance, direct fire at level 3 with a suppressive effect but with no chance of target damage, indirect fire at level 2 and communicated information at this level. Level 1 means no information.

2.1.3 Markov Process

The interplay of the probabilities of acquiring and losing target location information (in the old CARMONETTE) as above described is a Markov process. It is mechanically simple but theoretically complex. It can be manipulated by altering probability values to acquire targets at any desired rate (for given parameters) and to lose them at any desired rate. Thus, it can give the appearance of simulating limited-acquisition behavior. For example, the probabilities can be adjusted so that a very small number of distant targets are retained at any given time. This is reasonable. However, it cannot be made to pick up only one target out of many distant ones and retain and focus on that target. Herein lies the central difficulty of the Markov process modeling.

2.2 SEARCH/DETECTION MODEL

The set of algorithms developed by Dr. R. Zirkind for detection and recognition are the following.[1]

The cumulative probability of detection $P_d(t)$ for random search of a real scene by an observer employing an electrooptical device, e.g., image intensifier, TV or FLIR, where the scene information is displayed is given by

$$P_d(t) = P_\infty(r) \left[1 - e^{-(\eta t/\tau N k)} \right] \tag{1}$$

where

$P_\infty(r)$ = the probability at range, r, for unlimited viewing time

τ = mean time to detection in uncluttered scene

η = scan efficiency if scene area > projected area

N = area of scene/projected area of field of view ≥ 1

k = clutter term

A study of available literature has yielded an expression for the mean time, τ, namely

$$\tau_D = 0.52 + \frac{.016}{\phi(x)} \left[\frac{\Theta_D^2}{\Theta_T^3 \cdot C^2 B^n} \right] \text{, in seconds} \tag{2}$$

where

$\phi(x)$ = normal probability integral

X = $(C_r - 1)/.48$

C_r = target contrast/threshold contrast

Θ_D = angular subtense of display, degrees

Θ_T = angular subtense of target, degrees

C = percent contrast (target-background/background)

B = scene or display luminance in ft-Lamberts

n = 0.55 for 0.1 ft-L $\leq$ B $\leq$ 10 ft-L

The threshold contrast is defined here to be 2.65 times the value proposed by Blackwell.

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(1) A complete derivation of the algorithms and validation will be published in a forthcoming issue of the Journal of Defense Research.

The scan efficiency has been estimated to be given by the expression

$$\eta = \frac{1}{2} + \frac{1}{1+N}$$

or, $N \to \infty, \lim \eta \to 0.5$. The latter is in agreement with observations at Ft. Ord (CDEC).

Finally, in the event clutter is present, that is, target-like objects in the field-of-view, the mean time τ in Eq (2) will increase by the factor k. This factor is defined in Eq (3)

$$k = \nu \exp \left[\frac{.7}{[(1+\Delta\Theta) \cdot (1+\Delta C)]^2} \right] \quad (3)$$

where

ν = number of clutter points, $\nu \geq 1$

$\Delta\Theta$ = the ratio, angular subtense difference between the true target and non-target $\div$ angular subtense of true target.

ΔC = the ratio, contrast difference between target and non-target $\div$ contrast of the true target.

In a similar fashion an algorithm for the mean time for recognition has been developed. It is given by

$$\tau_R = 0.52 + \frac{\nu}{\left[\frac{(C-2.34)^{.639}}{\exp\left(\frac{1.65}{\Theta} - 1\right)} - 3.02 \right]}, \text{ in seconds} \quad (4)$$

where

ν = no. of target-like objects (targets and clutter) in field of view

C = Percent contrast

Θ = target size in milliradians

The cumulative probability of recognition is then

$$P_R(t) = P_\infty(\text{recognition}) \left[1 - e^{-\frac{t}{\tau_R}} \right]$$

2.3 INCORPORATING SEARCH/DETECTION ALGORITHMS

Incorporation of the Zirkind Model into CARMONETTE impinged primarily on those CARMONETTE submodels associated with surveillance and unit movement. The four levels of CARMONETTE target location information were retained but redefined operationally. The surveillance cycle and clock structure were retained but the Markov process of probability-per-cycle-vs-random-number gave way to the comparison of one random number with a cumulative probability over time from the inception of intervisibility to its interruption. A sector of search-responsibility for each combat unit was incorporated as a framework for the Zirkind Model along with a delineation of masked and unmasked terrain within that sector. Performance characteristics of thermal devices and image intensifiers were incorporated to employ the Zirkind Model.

A cursory description of the Zirkind equations as they now function within CARMONETTE is as follows. Equation (2) is employed to get a mean time to detection for current parameters for one field of view of the device. The resulting mean time is in turn modified by the area to be searched and by clutter as defined by Eq (3). This expanded mean time is then used in Eq (1) to get a probability of detection for one scan cycle as defined in CARMONETTE. The result of Eq (1) is then added to a cumulative probability of detection for the observer concerning the potential target. This process is repeated each scan cycle until the cumulative probability exceeds a random number (between zero and one) that had been drawn at the inception of the above process and the detection of this target occurs. This process is used only when the potential target is intervisible with the observer and is in the search area of the latter.

In the event that the observer is communicated information about the potential target before he detects it, his probability of detection is augmented.

Upon the occurrence of detection by the above process, a similar procedure is employed to tell when recognition occurs.

The observer can decide to fire at the target with detection information only but suffers a corresponding degradation in weapon performance. Or if he waits for recognition, he then realizes full weapon capability under the existing conditions.

If the potential target disappears from view (i.e., is no longer intervisible with the observer) before detection occurs, the procedure is halted and the accumulating probability erased. If the potential target is either far enough away or is showing sufficiently low contrast with his surroundings so that the viewing device limitations come into play, then he might remain undetected during the entire battle; this depends on the asymptotic probability of detection approached over time and on the particular value of the random number against which it is being compared.

2.4 LEVELS OF TARGET LOCATION INFORMATION

Previous versions of CARMONETTE modeled four states of knowledge about targets with accuracy of information increasing monotonically from State 1 through the intermediate states to State 4. The four states have had operational definitions as follows:

1 - No information: no firing
2 - "Nearest Square": artillery can be called on target
3 - "Erroneous pinpoint": artillery and direct fire (with no hits from direct fire)
4 - "Pinpoint": artillery and direct fire (assessed for probability of hit by direct fire.

The current version of CARMONETTE employs all four of the above states but changes their operational definitions in the following way. State 3 represents detection with resulting possibility of firing but with a degraded hit assessment. State 4 represents recognition (with full weapon performance if the seeker decides to fire). State 1 continues to represent no information. State 2 represents communicated information; artiller· can be called on State 2 targets.

2.4.1 Effect of Change

An advantage of operationally redefining information levels 3 and 4 to correspond respectively to detection and recognition is that it alligns these levels with a wealth of psychovisual experimentation and allows for direct input of experimental values.

The retention of level 2 as communicated information gave the following flexibility to model development. It was immediately usable information to the recipient of the communication (and was so programmed) in that he could temporarily narrow his search area in order to decrease the normal time to detection. Also level 2 information could, in the future, be employed to represent received information cues from such things as weapon signatures, dust clouds, movement, etc.

As the four levels are now defined, they do not lead to the firings on false targets that is so characteristic of previous CARMONETTE versions. (See the previous definition of level 3 above.) Such extra firing is characteristic of real battles and must now be included in a different manner. One way is to designate a portion of the combat units as false and handle the scoring accordingly.

2.5 SIMULATING TIME TO DETECTION

Experiments dealing with detection invariably describe time lapse, target parameters (such as size and contrast), bounds of search area, limiting performance of device employed, targets remaining undetected, and often the implication that the target remained intervisible with the observer throughout the experiment.

Any simulation of the search process should employ these parameters. It should be able to identify those times when unrestricted intervisibility with the target exist. It must be able to represent the times to detection for those targets that are found and it must be able to represent those targets that are never found.

The simulation itself can be in terms of "time-slices" or "critical events" or a combination of the two. The time-slice method identifies which targets are found by whom during each increment of time. Thus, the time when detection occurs is resolved only to the length of the time-slice. For many purposes this is adequate if the time-slice is reasonably small. The critical event method determines how long it takes from a starting time (such as the commencement of intervisibility) until the event (detection) occurs. The time when detection occurs is then resolved to the time resolution within the model. The pure critical event method is useful for our purposes only if the time to detection is of sufficiently short duration in terms of the parameters used in its calculation so that those parameters remain fixed over the ensuing time to detection.

2.5.1 Previous CARMONETTE Rule Structure

In CARMONETTE V and previous versions of the model, the time-slice method was employed with probabilities governing the acquisition of targets operating on a periodic basis. During each scan interval, a random number was selected and compared to a probability of "detection" per scan interval for each pair of seeker and potential targets that were intervisible. As long as a pair remained intervisible, this process continued until the seeker eventually detected the target. Once the target was detected by the seeker, a random number was selected and compared to a probability of losing the detection per surveillance interval. This duality of gaining and losing information applied to three levels of target information: (1) nearest square, (2) erroneous pinpoint, and (3) pinpoint.

The above process allowed an asymptote of sorts to be applied to the implicit cumulative probability (over time) associated with each of the three levels of target information. That is, the probabilities could be adjusted so that (for a given set of seeker-target parameters) the percentage of intervisibile targets acquired at a particular information level would not, on the average, exceed an appropriate asymptotic value.

This Markov process as employed by CARMONETTE had some serious deficiencies. In order to employ this target information model within CARMONETTE, it was necessary to use rather extensive equations concerning Markov processes to convert field data into the CARMONETTE model. Another drawback was that one could not write a rule guaranteeing the retention of in-the-gunner's-sight target without upsetting the delicate balance between the intent and outcome of the Markov probabilities. Also it was not easy to restrict the number of targets retained. A further drawback of using the Markov process was that as targets were killed, they entered a kind of trap state (by virtue of being dead) in terms of the Markov process which tended to upset the balance of the Markov probabilities (which are written as if no trap states existed). Finally, the biggest drawback to the Markov process was that it was generally misunderstood and, therefore, all-too-often improperly used.

2.5.2 New Rule Structure

A new procedure for processing target acquisition is used and is a compromise between time-slice and critical event methods. During continuous intervisibility between opposing combat units (tanks, APCs, etc.), cumulative probabilities of detection as a function of time are maintained for all combinations of intervisible opponents.* A given pair of opponents may be intervisible several times during a battle. For such a pair, the cumulative probability of detection of each about the other begins to grow at the time they become intervisible. The probability continues to grow during the time that they remain intervisible until either detection occurs, intervisibility ceases, or the probability of detection remains less than a random number selected to compare against it. The rate of growth of the probability is dependent upon the range of separation, viewing device employed, time available for search, etc. As these parameters change (c.f., the opponent's range of separation decreases), the rate of growth of the probability changes correspondingly. In order that the rate of growth of the probability remain respondent to changes in the parameters, a periodic check of the parameters is made. The period of time between checks of the parameters is called the surveillance interval and is dependent on the viewing device employed.

As stated, the probability ceases to grow if intervisibility ceases or detection occurs. When intervisibility ceases, the cumulative probability is erased (for each of the two opponents) and the process will commence anew when they next become intervisible. If detection occurs for one of the two opponents, about the other, the cumulative probability for the successful one is erased and the latter is given detection information (state 3) about his opponent. This detection has occurred by virtue of the cumulative probability exceeding a random number which was selected at the initiation of intervisibility.

Once detection occurs, then the same process is employed for recognition (state 4 information) as long as intervisibility continues with probabilities appropriate to recognition replacing those appropriate to detection.

The above procedure thus simulates times to detection and recognition from the inception of intervisibility and does so as a function of changing parameters. It also succeeds in isolating those opponents that are

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* Each opponent must also be in the search area of the other to be considered here.

never found by certain intervisible enemy simply because the cumulative probability reaches an asymptotic value before exceeding the corresponding random number.

The incremental probabilities of detection and recognition are constructed from the asymptotic probabilities associated with the existing parameter values along with the mean time to detect or recognize (also associated with existing parameter values) as given by the Zirkind equations.

The new rule structure on cumulative probabilities of detection at present applies to image intensifiers and thermal devices. Other seeker types remain connected to the Markov chain methodology. It is intended that this deficiency be corrected soon.

2.6 AREA OF SEARCH

In order to implement the Zirkind search/detection algorithm, it was necessary to identify the area of search for each combat unit. This is done by giving left and right search sector bounds to each combat unit and by sampling the terrain within the search sector to identify the actual portion of that terrain that is intervisible with the combat unit and hence available for search. These unmasked portions of land go under the name of intervisibility coefficients and their derivation is given next.

2.7 INTERVISIBILITY COEFFICIENTS

The intervisibility coefficients identify the fraction of land that is unmasked in the range interval containing the target. This is simulated by using a form of the line-of-sight routine to identify those terrain squares that are intervisible with the observer and that are also in his search sector. Such data is generated anew for an observer at each new terrain location, i.e., each time a combat unit crosses the boundary from one square to the next.

For the defending units, this generally needs to be done only once at the beginning of the battle (in the preprocessor). However, for the attacking units, it must be done on the order of 25 to 30 times per attacking unit, for a total of perhaps 800 times during a replication.

Thus, it behooves us to use an intervisibility formula that does not require a great deal of computer time, but one that still retains the essence of the problem description. The following method is relatively fast and employs the intervisibility conditions of the CARMONETTE terrain as viewed by the various observers.

The intervisibility coefficients for each observer consist of a set of numbers, each less than (or equal to) unity in magnitude. Each coefficient is associated with a range interval (0-500 meters, 500 to 1000 meters, etc.) within the observer's search sector and defines the fraction of the terrain in that range interval that is intervisible with the observer. The set of coefficients for each observer remains fixed as long as the observer remains in one location and has a fixed search sector. Initially, they are generated in the preprocessor and are calculated anew for a unit as it crosses a terrain boundary from one square to the next.

The calculation of intervisibility coefficients consists of running a set of terrain profiles from the observer position at equal angular increments (10^o) across his search sector, collecting the masked and unmasked portions of these profiles as a function of range interval, and thus generating the coefficients. Fig. 1 depicts one of these profiles. Beginning at (X_s,Y_s), the location of the observer, and heading outward along the profile, the height of each subsequent square along the profile line is employed with the observer's height and with the distance from the observer to calculate a mask angle, VM_n, in the vertical plane. This mask angle is then compared to the greatest mask angle found so far along the profile. If the mask angle just found exceeds the prevailing greatest mask angle, then the current square is intervisible with the observer and the most recent mask angle is retained as the greatest. Otherwise, the current square is said to be masked from the observer's view and the intervisibility of the next square along the profile is checked, etc. In this way, the fraction of intervisible squares within each range interval along the profile is determined. The same procedure is employed for the other profiles in the observer's search area. Then for each range interval, the average fraction of

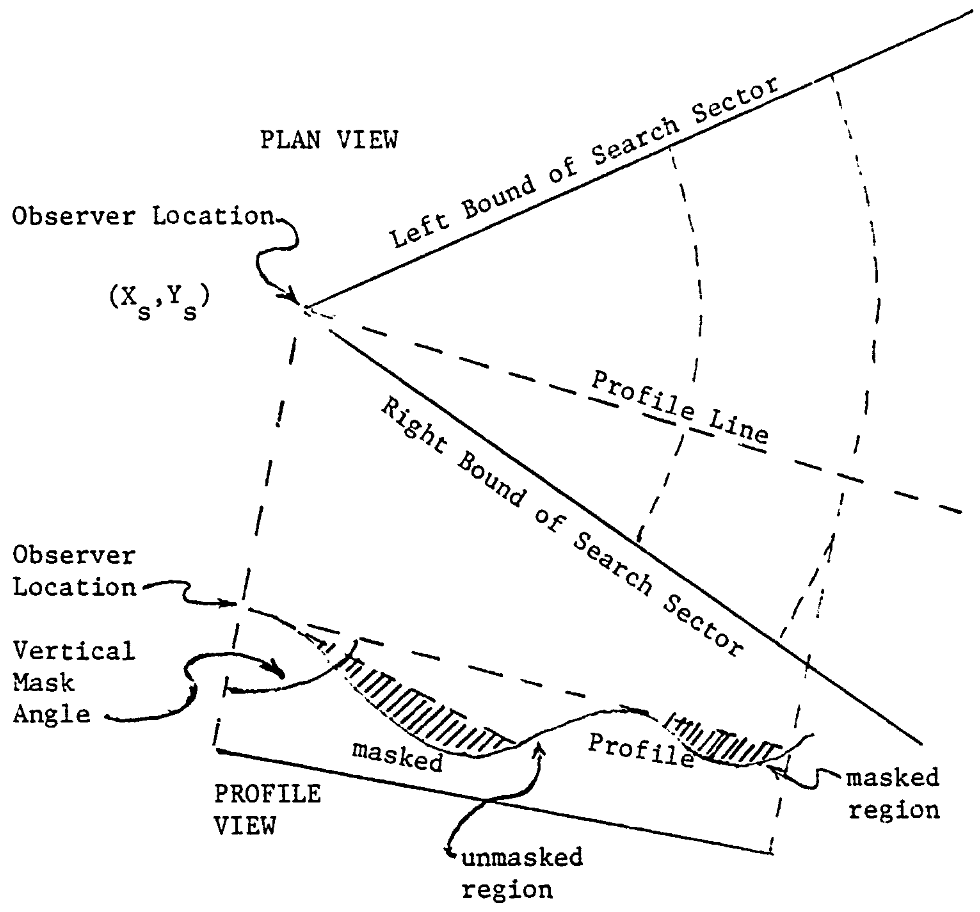


Fig. 1 - Profiling to Determine Unmasked Fraction of Search Area

unmasked terrain over the set of profiles is calculated and retained as the intervisibility coefficient for that range interval for the observer as long as he remains in that location.

The intervisibility coefficient is used along with the area of search to modify the mean time to detection that is given by the Zirkind algorithm in equation (2).

The intervisibility coefficients were essentially to be samplings of the line-of-sight function in CARMONETTE. As an indication of the accuracy of that sampling procedure, Fig. 2 was developed from intervisibility data generated in the two ways. First, the line-of-sight function was used to generate those map locations where a 5 ft target would be intervisible with a 5 ft observer located at the small triangle in the lower left corner of the map. Such areas remain unshaded. Secondly, the profiling procedure was employed to draw nine profiles from observers position at the triangle out to a distance of 3 km. Along each profile, a circle is drawn to indicate land that is unmasked to the observer. A perfect match of the two systems would result in circles showing up only in the unshaded areas. As can be seen from the figure, the fit is not perfect but is adequate.

2.8 DEVICE PERFORMANCE CHARACTERISTICS

The performance characteristics of the image intensifier and thermal devices are included in the modified CARMONETTE.

Those of the image intensifier were programmed for CARMONETTE IV and they are retained and used here with some modification to link up with the Zirkird search model. Input forms had been designed for CARMONETTE IV image intensifier characteristics and associated reflectances of targets and backgrounds along with night sky brightness measures. These were retained in so far as possible and used for the current computations. One characteristic, that of limiting performance or P_∞, was added as well as displayed contrast. A new input format was required for P_∞.

The performance characteristics of the thermal devices along with appropriate thermal contrasts between target and background, humidity and temperature inclusions for atmospheric attenuation, etc., were formatted, programmed into the preprocessors and made available for battle model inclusions. In the battle model these characteristics are programmed and linked to the Zirkind search model.

2.9 CLUTTER

Clutter is employed as a parameter in the current CARMONETTE model but does not vary as a function of terrain. Rather, it is introduced as a medium situation in terms of clutter as extracted from actual photos. It is programmed in as one clutter point per degree (horizontally) with ΔC being 0.1 and $\Delta\Theta$ varying over range: $\Delta\Theta$ is 0.5, 0.2, and 0.1 at ranges of 1250 m., 1500 m., and 2000 m. respectively; see footnote page 2-4.

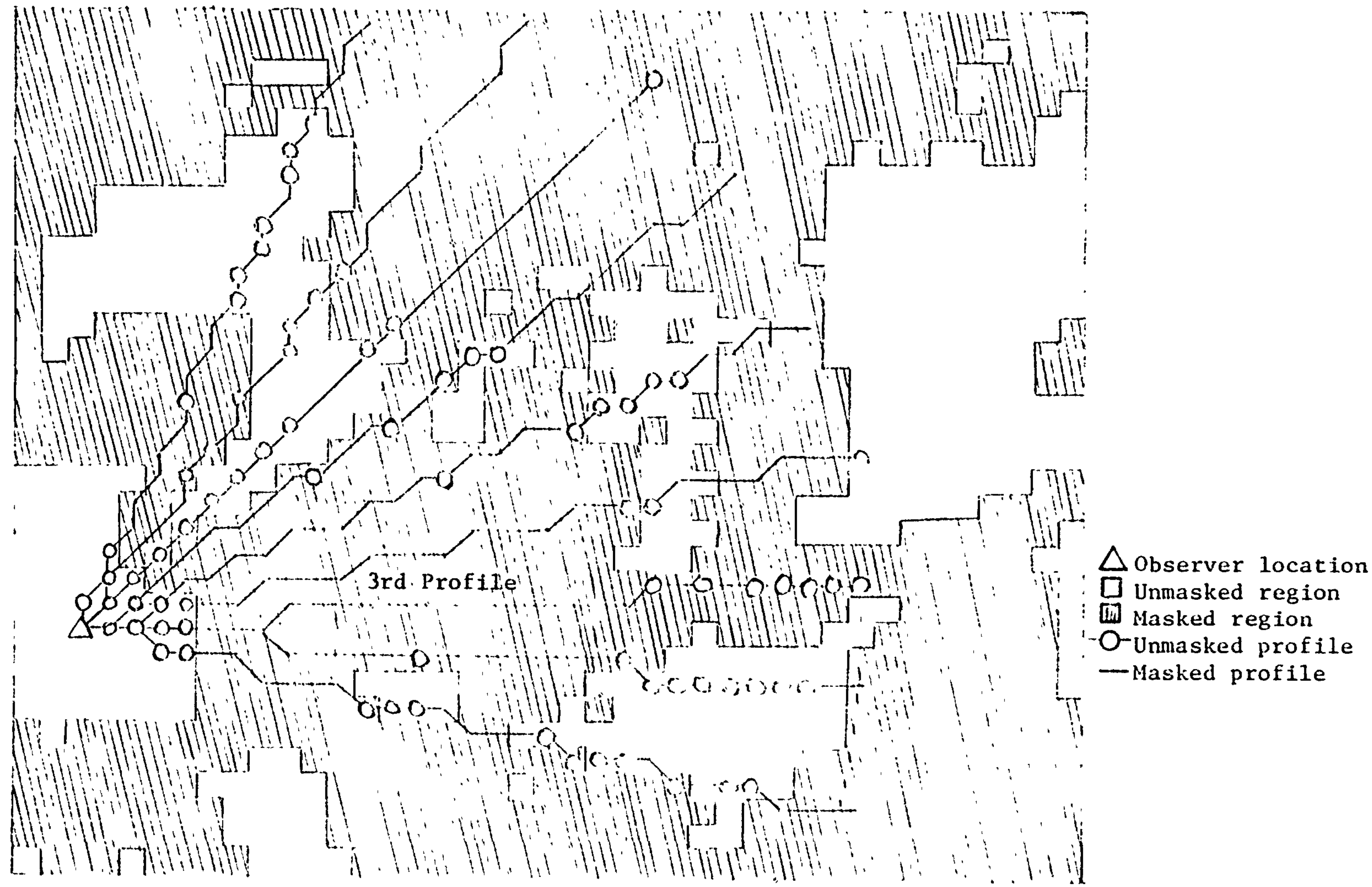


Fig. 2 -- Plan View of Intervisibility Coefficient Formulation Using Profiles and Range Intervals

3. SEARCH MODEL INCORPORATION

This section identifies, from the modeling and programming viewpoint, the modifications that were made to the CARMONETTE simulation logic to include a "Tactical Electrooptics Effectiveness Model" therein. Both thermal sights and image intensifiers were modeled. A basic structural change was made in the CARMONETTE target acquisition logic for more accurate simulation of the increase of target acquisition probabilities as a function of time. The general direction of search and sector of responsibility were included in the new logic as well as additional effects on search from the masking of terrain.

The modifications included logic changes, additional parameters, and changes in the employment of some of the previously included parameters. Additional data forms were drawn up for the inclusion of the new parameters. The implementation of the modifications necessitated changes to the first and second CARMONETTE preprocessor programs as well as to those of the battle model. The CARMONETTE program definition that was used as a starting point consisted of that set of rules as recorded in "CARMONETTE" in three volumes, November 1974, prepared by GRC-OAD under Contract DAAG39-74-C-0128 for US Army Combat Analysis Agency. The magnetic tapes possessing this rule structure were the following four:

Tape #	Program
1348	First Preprocessor
255	Second Preprocessor
2003	Battle Model
2918	Post Processor

These tapes contain the standard CARMONETTE V rule structure that was employed in the Phase I combat simulation runs reported in GRC report OAD-CR-121.

3.1 LEVELS OF INFORMATION ABOUT ENEMY UNITS

Four levels of information about enemy unit location and identification are retained under the modified rule structure. However, they are redefined operationally as follows:

Level	Name	Operational Definition
1	No information	No information.
2	"Nearest square" information	Communicated location information. Indirect fire can be called onto target, but no direct fire weapons can be employed against it. This information level allows the possessor to narrow his search sector temporarily and thus shortens the time to attain level 3.
3	Detection	Direct fire weapons can be employed against target with a damage assessment equivalent to 75% of that realized with level 4 information.
4	Recognition	Direct fire weapons can be employed against target with full weapon performance.

It should be noted that level 4 is defined to be a subset of level 3 and that level 3 is a subset of level 2. Thus, if a unit possesses level 3 information about a target, then that target is at least detected; the possession of level 3 information does not preclude the simultaneous possession of level 4 information.

3.2 SEARCH ALGORITHM

The search algorithm that was employed included the set of equations reported by Dr. Zirkind in his first Monthly Management Report to the Night Vision Laboratory in January 1976. These equations resulted in a mean time to detection, τ(sec), and an asymptotic value for a specific viewing device (P_∞) as functions of parameters associated with targets that are intervisible with a seeker. Also included therein, and included in the CARMONETTE search model, is the area of search by the seeker and a degradation in performance due to clutter. Mean time to recognition as reported by Dr. Zirkind, and an asymptotic value of the viewing device are also included in the CARMONETTE model.

3.3 DETECTION PROCESS FOR ONE SCAN CYCLE

One way of looking at the interaction of the Zirkind search model with CARMONETTE is in terms of a single scan cycle. This examination allows one to see the details of most of the newly incorporated program. The remaining details are addressed in the section BOUNDARY CROSSING MODIFICATIONS. In Fig. 3, a schematic drawing of the detection process for one scan cycle is depicted. It begins with the parameters for one observer and one potential target; it ends with an answer of success or failure of detection.

Shown in the left-hand portion of Fig. 3 are parameters that give rise to a calculated mean time to detection under current conditions. The parameters are dependent on the viewing device, display luminance, angular size and contrast of target, extent and complexity of search area, on prior information communicated about the target, and on observer conditions (suppression and/or focus on other targets) leaving him less than full time for search. Each of these parameters will be discussed in terms of their origins and interactions within the program.

On the right-hand side of Fig. 3 are the remainder of calculations used to convert the observer-target parameters into success or failure of target acquisition during the scan cucle. First a mean or average time to detection is calculated. From the mean time, a probability of detection per scan cycle is generated. The latter is then combined with a cumulative probability over time to create a new cumulative probability of detection over time. The length of time represented here is the elapsed time since the observer began searching for this target. The search process began when the target became intervisible with and in the search area of the observer. The new cumulative probability is then compared with a random number that was drawn when the search began. If the random number is still greater than the cumulative probability, then search

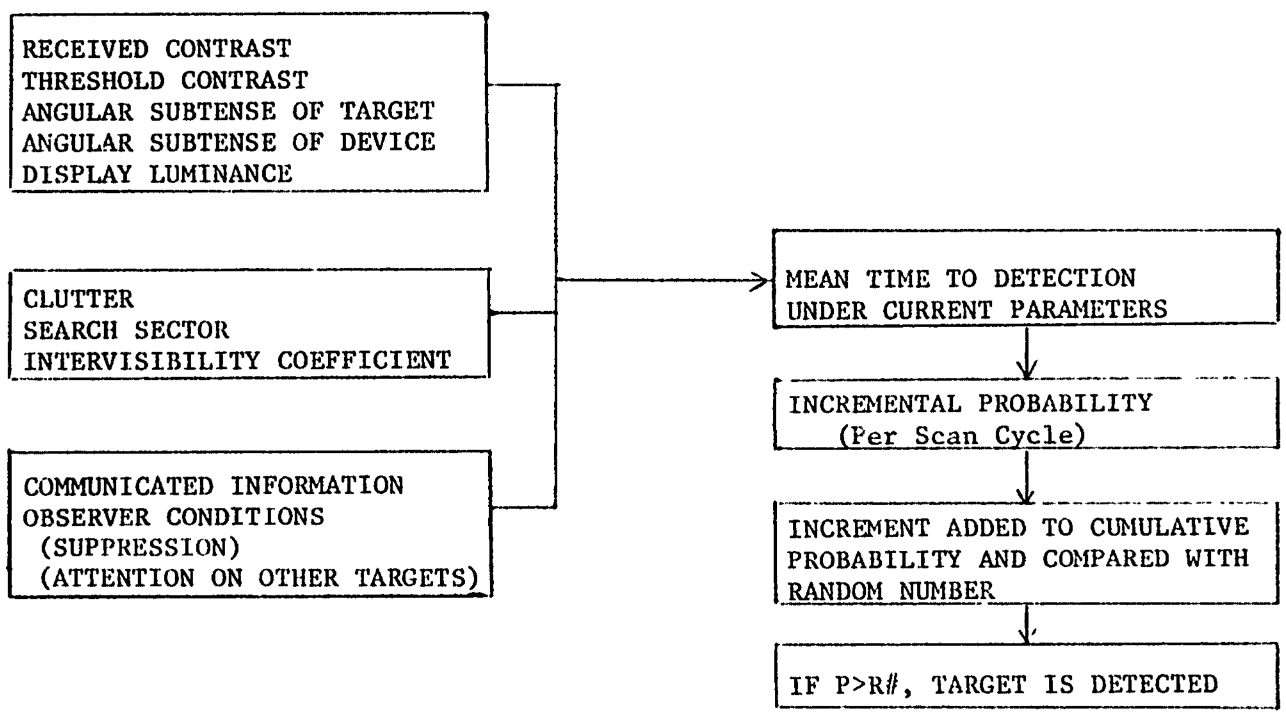


Fig. 3 - Detection Process for One Scan Cycle

will continue during the next scan cycle. Otherwise detection has occurred: the random number and the accumulating probability are erased; level 3 information (detection) is given to the observer; a new random number is determined and a similar process begins accumulating a probability of recognizing the target over subsequent scan cycles.

The probability calculations and computer storages thereof will be taken up in greater detail following the development of the observer-viewing device-target parameters shown in Fig. 3.

3.4 SEARCH PARAMETERS

The mean time to detection, τ_D in seconds, for a single uncluttered field of view with the viewing device is given by

$$\tau_D = 0.52 + \frac{.016}{\Phi(X)} \left[\frac{\theta_D{}^2}{\vartheta_t^3 C^2 B^{0.55}} \right] \tag{5}$$

where

C = received target contrast in percent

$\Phi(X)$ = normal probability integral

$X = (C_r - 1)/0.48$

$C_r = C/C_t$

C_t = threshold contrast in percent

ϑ_t = angular subtense of target in degrees

θ_D = angular subtense of device display in degrees

B = display luminance in ft-Lamberts

The calculation of Eq (5) for each appropriate observer-target combination is performed at the end of each surveillance interval in the subroutines IMADET and THERM for observers using image-intensifiers and thermal viewing devices, respectively. Complete descriptions of the parameter derivations leading to Eq (5) are given in the reports of the two subroutines, IMADET and THERM.

After equation (5) is calculated, the next step is to modify the calculation of mean time to detection by area of search, clutter, and observer parameters (level of information, amount of suppression and focus on other targets). These modifications are performed in the subroutine DETREC.

3.4.1 Area of Search

The area of search comprises a search sector and portions of land visible within it. The sector of search for each combat unit is defined by a left and right bounding line running through the unit's position and by the fraction of land visible to the unit in each of six range intervals within his sector of search.

The bounding lines (measured in degrees counterclockwise from due East) are input on cards* for each combat unit and are stored via the first preprocessor in the array IANG (48). They remain fixed throughout a run. Although they now remain fixed in direction, the framework of data storage and operational definition of search area provides the basis for making these bounds dynamic in the future.

Intervisibility Coefficient. Within the search sector, the fraction of land visible to the observer is called the intervisibility coefficient and is necessary to the search model to identify those areas in a range interval that includes a potential target and are unmasked by intervening terrain. The coefficient is a fraction and represents that portion of the terrain within the search angle of the seeker and within the range interval occupied by the potential target that is intervisible with the seeker. For larger fractions, greater amounts of time must be taken by the observer for search. This coefficient is constructed from terrain values in the second preprocessor and is a function of range to potential target and the particular terrain masks that occur in a combat unit's sector of responsibility. The number of range intervals is six; thus, six such coefficients are stored for each combat unit. At the time a combat

*Input is on the UNIT 3 cards in columns 19 through 24: the left bound, θ_{ℓ}, is placed in columns 19 through 21, and the right boundary, θ_r, in columns 22 through 24. See Fig. 14.

unit crosses a terrain boundary from one grid location to the next (in the battle model), a new set of intervisibility coefficients is calculated for it in terms of its new location and sector of responsibility. Then during the search process, the coefficient appropriate to the target range increment is selected for employment in arriving at a mean time to detect. The intervisibility coefficients are stored in the array FR (48,6,2).

3.5 CLUTTER

Clutter is introduced as a factor to extend the mean time, τ_D, to detect. As now programmed, it does not vary as a function of terrain. Rather it is introduced as a medium situation in terms of clutter as extracted from actual photos.

The defining equation for the clutter factor, K, is

$$K = \nu \exp \left[\frac{.7}{\left[(1 + \Delta\theta)\ (1 + \Delta C)\right]^2} \right] \tag{6}$$

where

ν = number of clutter points, $\nu \geq 1$

$\Delta\theta$ = the ratio: angular subtense difference between the true target and non-target ÷ angular subtense of true target.

ΔC = the ratio: contrast difference between target and non-target ÷ contrast of true target.

The clutter factor is programmed in as one clutter point per degree (horizontally) with ΔC being 0.1 and $\Delta\theta$ varying over range and fitting the following three points: $\Delta\theta$ is 0.5, 0.2, and 0.1 at ranges of 1250 M., 1500 M., and 2000 M. respectively.

3.6 OBSERVER PARAMETERS

The observer parameters that are currently programmed to further modify the mean time to detection, τ_D, are (1) the observer's degree of suppression from incoming fire and (2) his level of information concerning the potential target.*

*A third observer parameter concerns his attention on other targets. It does not modify the mean time to detect; rather, after he has two recognized targets, he cannot enter surveillance again until one of those two is known to be dead.

If the observer is partially suppressed by either direct or indirect fire, the program doubles his mean time to detection.*

If the observer has been communicated information about a potential target (and therefore, has level 2 information) the mean time to detect, τ_D, is cut in half to reflect a momentary decrease in the search area because of the improved information (level 2).

3.7 TACTICAL TIME TO DETECTION

The foregoing parameters (clutter, observer conditions, etc.) combine to provide a tactical mean time to detect which is coded in the subroutine DETREC. The latter is called from either IMADET or THERM depending on the sensing device employed. The tactical mean time to detection, τ_t, is

$$\tau_t = \left\{ K \frac{S}{V_f} I_c S_p I_2 \tau_D \right\} \Bigg/ \left\{ 0.5 + \left[(V_f + S) \Big/ V_f \right]^{-1} \right\} \quad (7)$$

where

τ_t = tactical mean time to detection in seconds

K = clutter factor

S = observer search sector, degrees

V_f = device horizontal field of view, degrees

I_c = intervisibility coefficient, a fraction

$S_p = \begin{cases} 2 \text{ if observer is partially suppressed} \\ 1 \text{ if not} \end{cases}$

$I_2 = \begin{cases} \frac{1}{2} \text{ if observer already has level 2 information on target} \\ 1 \text{ if not} \end{cases}$

τ_D = mean time to detect target when in device field of view and uncluttered field.

3.8 CUMULATIVE DETECTION PROBABILITY

After the tactical mean time to detection is calculated from the current values of the appropriate parameters, it must be converted into a probability of detection for one scan cycle (see right-hand side of

*If the observer is pinned down by incoming fire, he doesn't get a chance to do surveillance at all. That determination is made in the subroutine SURV which calls IMADET and THERM.

Fig. A-1). This is done as follows:

$$p_d = P_\infty \left[1 - e^{-C_s/\tau_t} \right] \qquad (8)$$

where

p_d = probability of detecting target in this scan cycle

C_s = scan cycle in seconds

τ_t = tactical mean time to detect target in seconds

P_∞ = asymptotic or limiting probability of detection due to limiting performance of viewing device under current conditions.

The next step is to add the probability per scan cycle to the cumulative probability that has been growing since intervisibility began between the observer and this potential target. To do this, we need both the cumulative probability and P_∞ representing the asymptotic performance of the viewing device. First we shall set down the equation to get the new cumulative probability and then identify the origin of the components. The new cumulative probability of detection is

$$P_n = P_{n-1} + p_d \left[P_{\infty n} - P_{n-1} \right] \qquad (9)$$

where

P_n = cumulative probability of detection over the n scan intervals that have elapsed since the target became intervisible with the observer and was in the observer's search sector. The n^{th} scan interval represents the one under investigation.

P_{n-1} = cumulative probability of detection over the n-1 scan intervals that had elapsed before the current (n^{th}) scan interval began.

p_d = probability of detection for current (n^{th}) scan interval as defined by Eq (8).

$P_{\infty n}$ = asymptotic probability for conditions of n^{th} scan interval as defined by the limiting performance of the observer's viewing device. P_∞ is dependent on the range to target, target size, exposure, etc. This is the same value as P_∞ in Eq (8).

The new cumulative probability, P_n, of detection is now compared with a random number that was selected at the inception of intervisibility between observer and target. This same random number has been compared in the past with the cumulative probabilities, P_{n-1}, P_{n-2}, etc., on previous scan intervals and found to exceed them in value. Otherwise, detection would already have occurred. If now P_n is greater than or equal to the random number, detection is defined to occur and level 3 information (MI3) is given to the observer about this target. Other potential targets for this observer are also being processed during this scan interval with their respective P_n's and random numbers.

3.8.1 Origin and Storage of Probability Parameters

The cumulative probability of detection for each observer-target pair is stored in the array RECG (63,48). The observers include the 48 combat units and the 15 command units (48 + 15 = 63) on each side and the potential targets include the opposing 48 combat units. Stored also in the RECG array are the corresponding random numbers that are compared with the accumulating probabilities during each scan cycle.

The RECG array is a packed array and is described in full in the description of new data arrays. It is initialized for both sides at the beginning of each battle replication (in subroutines LSCHEK and AOS) and at that time a random number is selected for each intervisible observer-target pair when the target is in the search sector of the observer. Then, during the ensuing scan intervals for each observer, the probabilities of detection (dependent on the observer-target parameters) grow and are compared with their respective random numbers until detection occurs.

Whenever a combat unit crosses a boundary from one terrain square to an adjacent one, the boundary-crossing subroutine BOUNDX calls the subroutines LSCHEK and AOS for a complete update of the RECG array concerning the boundary crosser and all opposing combat units. In those cases where intervisibility ceases, the corresponding random number and cumulative probability are erased. In those cases where intervisibility begins because of the boundary crossing and the search sector rule is not violated, then a new random number is selected and entered into the appropriate place of the RECG array for the observer-target pair to initiate the detection process.

3.8.2 Limiting Performance of Viewing Device

The limiting performance, P_∞, of both the thermal and image intensifier devices is read into the CARMONETTE preprocessor from input cards (format 37C). The dependent variables include target size (element size index), range to target, and target posture (in open or hull defilade) for both detection and recognition probabilities. The range to target is placed on the input form for four values of P_∞ (for P_∞ = 1, .75, .50, 0) for each combination of other parameters (See Fig. 10). These are stored in PINA (12,40,4). Within the battle model, interpolation then provides the specific P_∞ value to be used for a given range to target.

3.9 TARGET RECOGNITION

The process depicted in Fig. A-1 represents detection methodology for one scan cycle. A similar process is employed for target recognition once detection has occurred. Only the parameters are different. These calculations also occur in the subroutine DETREC. A mean time to recognition is calculated via the equation:

$$\tau_r = \frac{\nu}{\left[\dfrac{(C - 2.34)^{.639}}{\exp\ (.0945/\theta_t - 1)} - 3.02\right]} \tag{10}$$

where

τ_r = mean time in seconds to recognize the target

ν = number of clutter points in field of view (one per degree horizontally)

C = received contrast in percent

θ_t = angle subtended by target on display, degrees

Both θ_t and C are developed in the same way for both detection and recognition. The mean time to recognition is used to get a probability per scan interval as follows:

$$P_r = P_\infty \left(1 - e^{-\frac{Cs}{\tau_r}}\right) \tag{11}$$

where

p_r = probability of recognizing target during one scan interval

P_∞ = asymptotic or limiting probability due to device performance (found from PINA array and interpolation)

Cs = scan interval in seconds

τ_r = mean time in seconds to recognize target

The per-scan-cycle probability is used to get a new cumulative probability, Pm, of recognition for the m^{th} scan cycle (m = 1 at time detection occurs) where

$$Pm = Pm\text{-}1 + p_r \left[P_\infty - Pm\text{-}1 \right] \tag{12}$$

and the definitions of parameters are the same as those for Eq (a4) with the word "recognition" replacing "detection."

The cumulative probability of recognition, Pm, is then compared against its waiting random number which was drawn at the time detection occurred and the recognition process began. If Pm is now greater than or equal to the random number, recognition occurs and the observer is given level 4 information (MI4) about the target. Otherwise, he has not yet recognized this target.

This concludes the description of the detection and recognition process per scan cycle. For more detail concerning them, see the individual reports of the subroutines, SURV, IMADET, THERM, and DETREC and the functions CONTST and PHIX.

3.10 BOUNDARY CROSSING MODIFICATIONS

The other major modification to the CARMONETTE battle model to incorporate the Zirkind search model centers on the time at which a combat unit crosses the boundary from one terrain square to an adjacent one. Part of this has been touched upon in the context of detection and recognition per scan cycle. It includes the changes that are necessary to erase or initiate the detection process as intervisibility and search sector geometry changes via the boundary crossing. The subroutines employed for the modification are LSCHEK and AOS and they keep track of the enemy in a combat unit's search sector that are intervisible with him.

3.10.1 Enemy in Search Sector

The list of enemy units in each combat unit's search sector is constructed in the second preprocessor (for both Blue and Red combat units) and is available at the beginning of battle. It is updated when a unit (on either side) crosses the boundary from one terrain square to the next (in the battle model).

The location within the second preprocessor where the list of "enemy in search sector" is first constructed is in the subroutine LSCHEK that is found in the OVERLAY (DIAGTX,1,0). From LSCHEK the new subroutine AOS is called to determine which enemy units are in whose search sector.

After the battle begins, modifications are made to "enemy in search sector" whenever intervisibility conditions change and this occurs only as combat units cross the boundary from one terrain square to an adjacent one. At the time of the crossing by a unit on either the Blue or Red side, that unit's "list of enemy in search sector" is modified. Also, all enemy units who listed the boundary crosser among their lists before the actual boundary crossing are checked to see if the boundary crosser should now be erased from their lists. All enemy units who became intervisible with the boundary crosser by virtue of its entering the new square are checked to see if the boundary crosser should now be included in their lists.

The location within the battle model where the list is modified is in the subroutine BOUNDX that is found in OVERLAY (ZAPXXX,1,0). From BOUNDX the subroutines LSCHECK and AOS are called to determine the modifications that are to be made.

Test for inclusion in search sector. The test employed in determining whether an enemy unit is in a combat unit's search sector is as follows:

Let X_s, Y_s be the observer location,

X_t, Y_t be an enemy unit location,

Θ_ℓ, Θ_r be the directions from the observer identifying the left and right boundaries of his search sector. Θ_ℓ and Θ_r will have values ranging from 0 degrees up to (but not including) 360 degrees. $\Theta = 0$ corresponds to the direction East, 90 to North, 180 to West and 270 to South (from the observer).

Then the direction, Θ_t, from the observer to an enemy unit is represented by the angle whose tangent is

$$\frac{Y_t - Y_s}{X_t - X_s}$$

These variables are depicted in the Figs. 4 and 5. The FORTRAN subroutine ATAN2 ($Y_t - Y_s$, $X_t - X_s$) is employed to determine the angle, Θ_t. The output of ATAN2 is in radians and varies from $-\pi$ to $+\pi$. This output is converted in the CARMONETTE subroutine, AOS, to range from 0 degrees to 360 degrees.

In those cases where $\Theta_\ell > \Theta_r$ (as in Fig. 4), the test determining whether the target is in the search sector is

$\Theta_\ell \geq \Theta_t \geq \Theta_r$ implies that the enemy unit is in the sector.

On the other hand, in those cases where $\Theta_\ell < \Theta_r$ (as in Fig. 5, the test is

$\Theta_\ell \geq \Theta_t$ OR $\Theta_t \geq \Theta_r$ implies that the enemy unit is in the sector.

The above tests are made only on enemy combat units that are intervisible with the observing unit.

3.10.2 <u>Intervisibility Coefficient Construction</u>

Other modifications that occur at boundary crossing include the construction of new intervisibility coefficients for the combat unit that is now crossing the boundary to the new terrain square. The subroutines that were added to accomplish this are COVME and PCTSEE. They are employed for initially constructing those coefficients for all combat units in the 2nd preprocessor; then as each combat unit moves anew, they are reconstructed for this new location.

The intervisibility coefficients identify the fraction of land that is unmasked in the range interval containing the target. This is simulated by using a form of the line-of-sight routine to identify those terrain squares that are intervisible with the observer and that are also in his search sector.

The intervisibility coefficients for each observer consist of a set of numbers, each less than (or equal to) unity in magnitude. Each coefficient is associated with a range interval (0-500 meters, 500 to

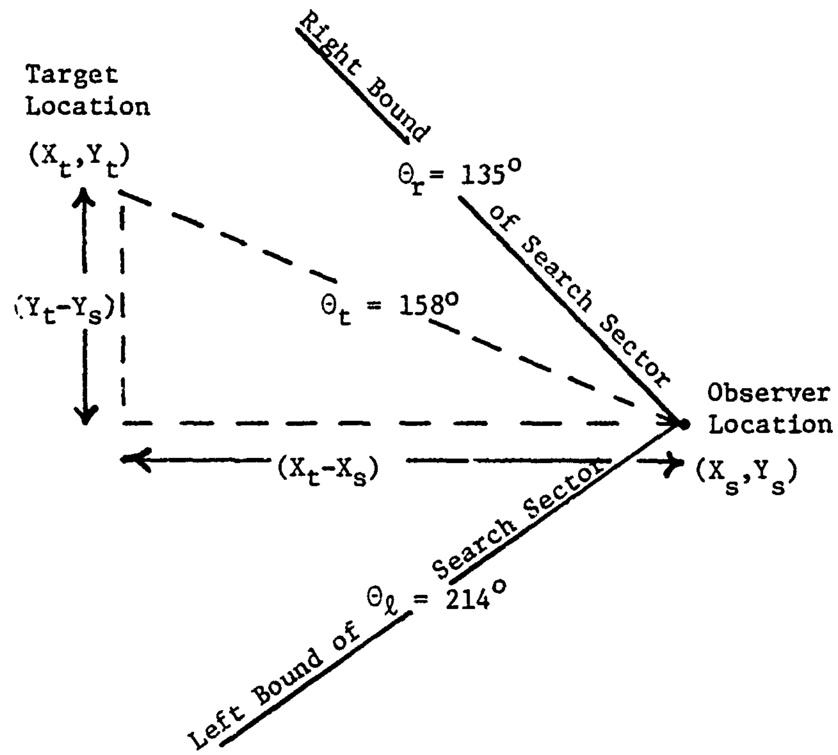


Fig. 4 - Target Location Within Observer's Search Sector when $\Theta_\ell > \Theta_r$.

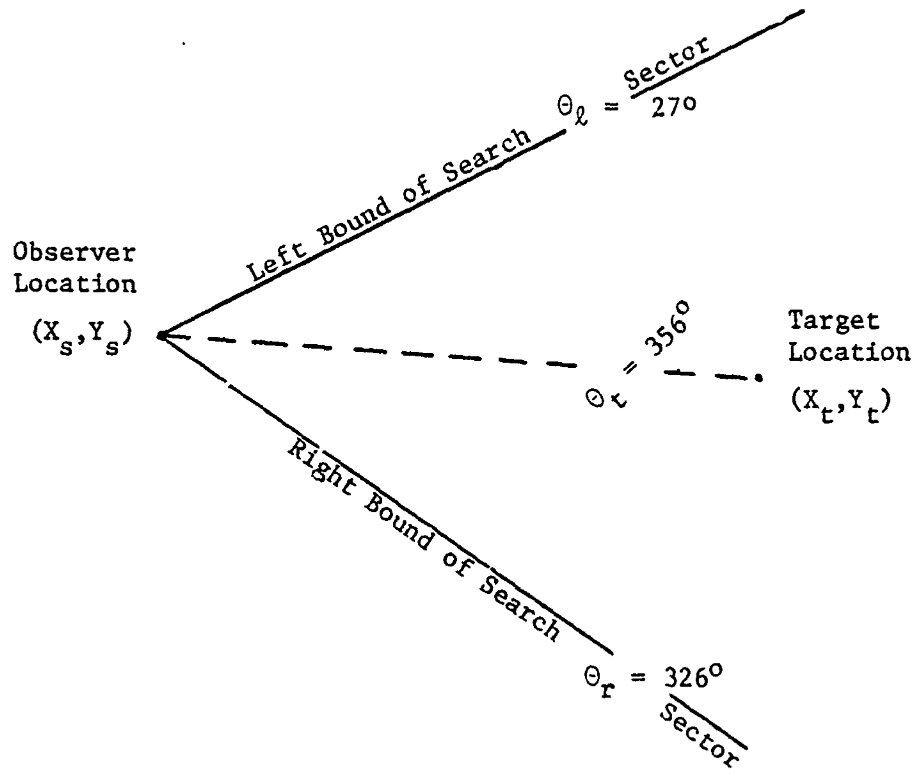


Fig. 5 - Target Location Within Observer's Search Sector when $\Theta_\ell < \Theta_r$.

1000 meters, etc.) within the observer's search sector and defines the fraction of the terrain in that range interval that is intervisible with the observer.

The calculation of intervisibility coefficients consists of running a set of terrain profiles from the observer position at equal angular increments (10^{o}) across his search sector, collecting the masked and unmasked portions of these profiles as a function of range interval, and thus generating the coefficients. Fig. 6 depicts one of these profiles. Beginning at (X_s, Y_s), the location of the observer, and heading outward along the profile, the height of each subsequent square along the profile line is employed with the observer's height and with the distance from the observer to calculate a mask angle, VM_n, in the vertical plane. This mask angle is then compared to the greatest mask angle found so far along the profile. If the mask angle just found exceeds the prevailing greatest mask angle, then the current square is intervisible with the observer and the most recent mask angle is retained as the greatest. Otherwise, the current square is said to be masked from the observer's view and the intervisibility of the next square along the profile is checked, etc. In this way, the fraction of intervisible squares within each range interval along the profile is determined. The same procedure is employed for the other profiles in the observer's search area. Then for each range interval, the average fraction of unmasked terrain over the set of profiles is calculated and retained as the intervisibility coefficient for that range interval for the observer as long as he remains in that location. These coefficients are stored in the array FR(48,6,2).

The intervisibility coefficient is used along with the area of search to modify the mean time to detect that is given by the Zirkind algorithm.

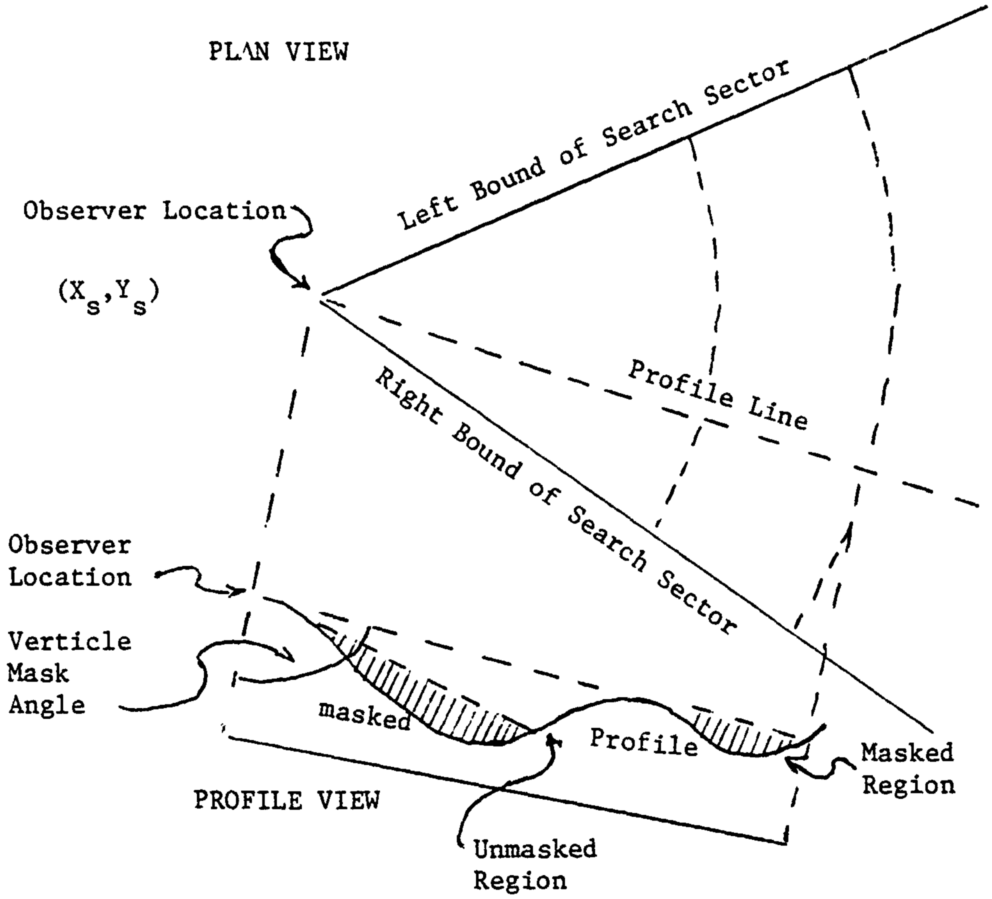


Fig. 6 - Profiling to Determine Unmasked Fraction of Search Sector

3.11 NEW DATA ARRAYS

The incorporation of the Zirkind search model required the addition of 26 new data arrays to the common storage CMAIN. A listing of them is found in Table 1 with a brief identification of contents and size. Most are self-explanatory and correspond directly to new data that is introduced on the new input data forms and described in connection with them. The three arrays RECG, IANG, and SECH are bit-packed, so additional explanation of those three follows the table. Also to avoid confusion, the arrays PINA and FR are expanded.

Table 1 - New Data Arrays in Common CMAIN

No. of Words	Array Name		Identification
3024	RECG(63,48)	:	Cumulative Prob. & Random No.
48	IANG(48)	:	Left & Right Bounds of Search Sector (48 combat units on each side)
96	SECH(48,2)	:	Enemy in LOS & in Search Sector (48 combat units, 2 sides)
1920	PINA(12,40,4)	:	P_∞ for II & for Thermal (12 sensor types, 40 combinations of range and target size, 4 combinations of information level and target posture.)
576	FR(48,6,2)	:	Intervisibility Coefficients (48 combat units, 6 range int., 2 sides)
1	HO	:	Amount of water vapor in one km. of viewing path used to attenuate thermal signal through atmosphere
96	ADSP(6,16)	:	Display illuminance (in lumens/$m.^2$) for 6 II devices and 16 background reflectances
6	IGAIN(6)	:	Optical gain for 6 image intensifier devices
6	OFND(6)	:	Device F-Number for 6 image intensifier devices
6	ELDV(6)	:	Field of view for 6 II devices, degrees
6	FCTPCT(6)	:	Communication links between subroutine PCTSEE and COVME while constructing intervisibility coefficents for a single combat unit
6	FRCT(6)		
48	TGDIM(3,16)	:	3 Dimensions of 16 Target Classes, meters
6	FOVAZ(6)	:	Horizontal field of view in degrees for 6 thermal devices
6	FOVEL(6)	:	Vertical field of view in degrees for 6 thermal devices
6	MAGTH(6)	:	Magnification for 6 thermal devices
6	DHTH(6)	:	Display width in meters for 6 thermal devices
6	DVTH(6)	:	Display height in meters for 6 thermal devices
6	CONSTH(6)	:	Contrast at display saturation for 6 thermal devices
6	SRESTH(6)	:	System resolution in milliradians for 6 thermal devices
6	VWDTH(6)	:	Viewing distance in meters for 6 thermal devices
6	RESITH(6)	:	Impulse response in milliradians for 6 thermal devices
2	EB(2)	:	Mean background emittance (used for thermal signal for two backgrounds)
1	TB	:	Background temperature of battlefield in degrees Kelvin
16	TAGEMT(16)	:	Mean target emittance for 16 target types
16	TMPDIF(16)	:	Temperature difference in degrees Celsius between target and background for 16 target types
5928 = Total Words			

3.11.1 Storage of Cumulative Probabilities and Random Numbers

Array "RECG(63,48)" containing 3024 words has been added to the labeled common CMAIN. This array contains the cumulative probabilities of detection /or recognition and the random numbers against which these probabilities are compared periodically to determine the time to detect or recognize. During the time when an enemy unit is intervisible with and in the search sector of a unit, both portions of this table for that unit are working storage (until recognition occurs). Otherwise they are set to zero.

There are 15 bits per entry: Red seekers and Blue potential targets are represented in the left half of each word; Blue seekers and Red potential targets are represented in the right, i.e.,

	RED SEEKER		BLUE SEEKER		
	Cum. Prob.	Random Number	Cum. Prob.	Random Number	
RECG(1,1)	60 Blue 46 tgt #1	45 Blue 31 tgt #1	30 Red 16 tgt #1	15 Red 1 tgt #1	
RECG(1,2)	Blue tgt #2	Blue tgt #2	Red tgt #2	Red tgt #2	
		⋮			SEEKER #1
RECG(1,48)	Blue tgt #48	Blue tgt #48	Red tgt #48	Red tgt #48	
RECG(2,1)	Blue tgt #1	Blue tgt #1	Red tgt #1	Red tgt #1	
		⋮			
RECG(63,48)	Blue tgt #48	Blue tgt #48	Red tgt #48	Red tgt #48	

Example: To get random number,

```
   IBIT = (MSIDE-1)*30+1
  RANUM = KGET(RECG(MUNIT,NUNIT),15,IBIT)
```

To get cumulative probability,

```
   IBIT = (MSIDE-1)*30+1
 CUMPRB = KGET(RECG(MUNIT,NUNIT),15,IBIT+15)
```

3.11.2 Storage of Combat Unit Search Sector

Array "IANG(48)" has been added to the labeled common CMAIN. This array contains the left (Θ_ℓ) and right (Θ_r) bounds for each unit's search sector. Four angles are packed per sixty-bit word, where each addressable word is the unit number (or index 1-48), i.e.,

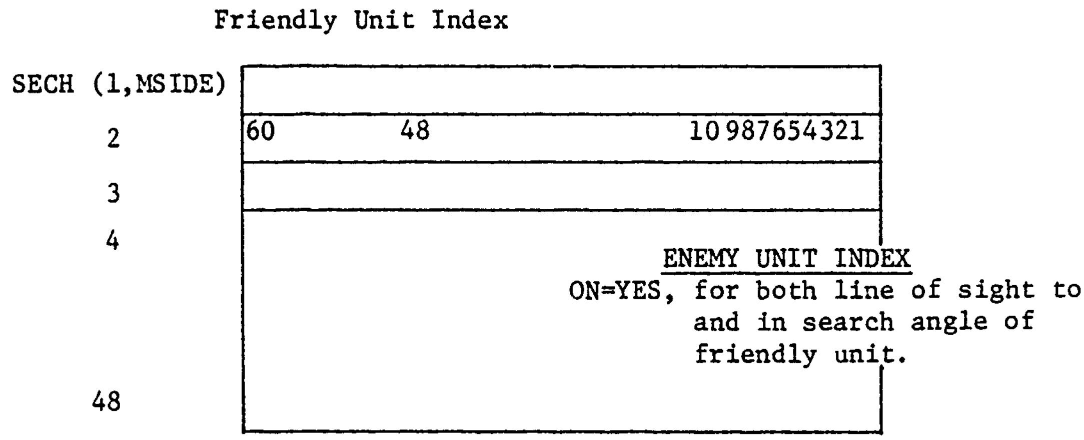
	RED UNITS		BLUE UNITS		
IANG (1)	Red Unit 1 Θ right	Red Unit 1 Θ ℓeft	Blue Unit 1 Θ right	Blue Unit 1 Θ ℓeft	60 bits
(2)	60 Red Unit 2 Θ_r 46	45 Red Unit 2 Θ_ℓ 31	30 Blue Unit 2 Θ_r 16	15 Blue Unit 2 Θ_ℓ 1	
(3)					
(4)		Red Unit 4 Θ_ℓ			
(5)				Blue Unit 5 Θ_ℓ	
.					
.					
.					
(48)	Red Unit 48 Θ_r				

Example: To retrieve RED "MUNIT"s (unit's) Θ_ℓ and Θ_r search sector angles

```
IBIT = (MSIDE-1)*30+1
  LA = KGET(IANG(MUNIT),15,IBIT)
  RA = KGET(IANG(MUNIT),15,IBIT+15)
```

3.11.3 Storage of Intervisible Enemy Units in Search Sector

Array "SECH(48,2)" has been added to the labeled common CMAIN. This array contains a yes/no (ON, OFF) condition bit for all friendly combat unit potential targets with both line-of-sight and are within-the-search-sector (IANG(48)). Bits 1-48 of each word show yes/no for each possible enemy unit as follows:



Example: To test for both LOS (line-of-sight) and search angle between I^{th} friendly and J^{th} enemy unit

```
      IB = KGET(SECH(I,MSIDE),1,J)
       IF (IB. EQ.0) GO TO (NO)
C YES
```

3.11.4 Storage of P_∞ Values for Detection and Recognition

Array "PINA (12,40,4)", containing 1920 words, has been added to the labeled common CMAIN. This array contains the distances in meters at which P_∞ (detection and recognition) has the values of 1.00, .75, .50, and 0, respectively, for each of 12 sensor types (the first 6 represent II devices and the second 6 thermal) against enemy of element size 0 to 9 for 2 states of concealment(open and hull defilade).

The arrangement of the array is more easily understood if the dimensions of (12,40,4) are replaced by (2,6,10,4,2,2) and identified by

Name	Dimension	Definition
LSC	2	Class of viewing device where, for this tabulation only, LSC = 1 means Image Intensifier and LSC = 2 means Thermal. In all other places, classes 2 and 3 are used for Image Intensifiers and Thermal respectively.
LST	6	Type of viewing device within the class categories.
IES	10	Element size index of target.
RNGE	4	Range to target in meters (for which $P_{\infty} = 1, .75, .50, 0$).
IL	2	Information level (detection = 1, recognition = 2) Note: only in this tabulation are these numbers used for detection and recognition
IC	2	Target posture where "in open" is 1, "hull defilade" is 2.

3.11.5 Intervisibility Coefficients

Array "FR(48,6,2)" containing 576 words, has been added to the labeled common CMAIN. This array contains the fraction of terrain in each of six range intervals within the search sectors of the 48 combat units on the Blue and Red sides. Each entry is real (as opposed to being integerized).

3.12 NEW SUBROUTINES FOR BATTLE MODEL

For the battle model, new subroutines and functions have been added and some original subroutines underwent fairly severe modification.

The new subroutines and functions, along with the modified ones, are described next under the format employed for the November 1974 publication of CARMONETTE. The names of the modified subroutines are IMADET, LSCHEK, SURV, and TGTACQ. The new subroutines are named AOS, COVME, DETREC, PCTSEE and THERM. The new functions are CONTST and PHIX.

AOS

Purpose: To determine if the enemy combat unit, JUNIT, located at IXJ, IYJ, is within a combat unit's (IUNIT) search sector.

Arguments: IXI, IYI (observing unit coordinates), IXJ, IYJ (enemy unit coordinates), LA, RA (left and right bounding direction, in degrees, of observing unit's search sector), ISIDE, IUNIT (side and unit number of observing unit), JUNIT (unit number of enemy combat unit), IB1 (a return variable containing a random number if JUNIT is found to be in search sector and containing a zero if not), labeled common MAIN.

Called by: LSCHEK

This subroutine determines the direction from a combat unit to an enemy combat unit and finds out if the enemy unit is in the search sector of the former. If so, a random number between zero and one* is returned via the argument IB1. Otherwise a zero is returned.

*The unit domain of random numbers is actually scaled from zero to 64/64 with the denominator implicit but not employed.

CONTST (Function)

Purpose: To determine the threshold contrast on a night vision device display.

Arguments: Angle subtended by target on display at observers eye in minutes of arc (VIS), display brightness (BRG) in foot-lamberts.

Called by: IMADET, THERM

The function CONTST determines the threshold contrast in terms of target angle and scene brightness. Threshold contrast is here defined to be 2.65 times that proposed by Blackwell. A two-way interpolation is employed to calculate the threshold. Data points presenting the threshold in terms of the logarithm of visual angle (angle in minutes of arc) and logarithm of adaptive brightness (brightness in foot-lamberts) as developed by Blackwell in 1946 are part of the function package.

After taking the logarithms of the arguments VIS (visual angle) and BRG (brightness) a first approximation to log brightness is found (among the data points) in the DO 10 loop. Then the same is done for log brightness within the DO 18 loop. If the value falls inside the data limits a two-way interpolation is then employed to find the threshold contrast as defined by Blackwell; the resulting value is then multiplied by 2.65 to provide the final value of threshold contrast. If, however, the value had fallen outside the data limits of the table, then the value of threshold contrast at the appropriate bound of the data table is used and then multiplied by the factor, 2.65. Within the table, the Blackwell threshold values vary between .01 and 1000*. Thus the final values of threshold contrast (after being multiplied by the factor of 2.65) vary between .0265 and 2650.*

*These values represent contrast rather than percent contrast.

COVME

Purpose: To construct the terrain intervisibility coefficients that are used to determine the distribution of land within a combat unit's search sector that is unmasked (or visible to that unit).

Arguments: IX, IY, IH, LA, RA (coordinates and height of combat unit and the left and right bounds of his search sector), labeled common MAIN.

Called by: LSCHEK

This subroutine is called (by LSCHEK) for each combat unit whenever it moves from one grid location to another. From the combat unit's new location, profiles are drawn at equiangular increments (every 10°*) within his search sector (subroutine PCTSEE performs the profiling) outward from the combat unit. Then for given increments of distance (each increment is 500 meters long*) along each profile the fraction of terrain that is visible to the combat unit is calculated and averaged over the set of profiles. The results--fractions representing the proportion of land visible to the combat unit within range increments in his search sector--are stored in FR MUNIT, I, MSIDE (I counts range intervals) for later use in the search algorithm (see subroutine SURV).

*The angular separation of 10° between profiles and the 500 meter range increments along the several profiles appear to give an adequate representation of the fractions of land visible to the observing combat unit. Each profile is extended through six increments and beyond that the fraction of land that is visible in the sixth increment is employed whenever intervisibility coefficients are called for.

DETREC

Purpose: To determine if detection or recognition occurs at this time for one observer and one potential target.

Arguments: IIDN (Seeker type), TAU (mean time to detection for one device setting), ISCAN (scan time); IWHO (seeker class), ITGT (target); DIS (range to target), RECCON (received contrast in %); JIIPR (return parameter: zero if no change in intelligence, non-zero otherwise), THETAT (received target angle in degrees).

Called by: IMADET, THERM

DETREC performs the task of generating the mean time to attain the next step in target acquisition, whether it be detection or recognition. After having calculated the mean time to the next step, this routine converts that time into a "probability per scan time" and combines this result with the attained cumulative probability. The result then is a new cumulative probability which is compared to a waiting random number to determine if target acquisition has now improved to either detection or recognition.

DETREC is entered under two different conditions. The first concerns an observer unit and a potential target that is not now detected by the observer (i.e., not on the MI3 list). The second concerns a detected target that is not yet recognized. In the first case, a mean time to detection in seconds for a single setting of the viewing device has been calculated prior to entry into DETREC. It is fed to DETREC as one of the input parameters (TAU). In DETREC, this mean time is further modified to arrive at an overall time to detection. The modifying factors are the region of search responsibility (search sector width modified by masked terrain in that region), clutter, and prior cues to the observer from communication or firing signature (if target is on the MI2 list).

Finally the overall time to detect is coverted to the number of scan intervals (EXPD) needed to detect. An asymptotic probability (P_∞) of detection over infinite time is next calculated for the current parameters and the cumulative probability, P_c (extracted from the appropriate place in the RECG arrays), is compared with it (Statement 118). If P_c is at least as large as P_∞, then the cumulative probability has already reached its asymptotic value and no new accumulation can be added to it. In this event the routine exits, setting JIIPR to zero. However, if P_∞ is greater than P_c, then the previously-calculated number of scan intervals needed to detect (EXPD) is converted to a delta probability via equation (1) for addition to the cumulative probability of detection (Statement 105).

$$\Delta P = (P_\infty - P_c)\left(1 - e^{-\frac{1}{EXPD}}\right) \qquad \text{Eq (13)}$$

The value of delta probability is then added to P_c, the current cumulative probability and returned to its place in the RECG array.

The new cumulative probability is rounded, integerized, and placed in JIIPR for comparison with the random number that was generated for this intervisibility stretch. If P_c is now greater than the random number, detection has occurred and the potential target is placed on the observer's M13 list (following statement 122). Otherwise the routine is exited with JIIPR set to zero.

The second way of entering DETREC occurs when an observer has detected the target but has not yet recognized it. In this case, control is transferred to statement 130 (after P_∞ is calculated) where a mean time to recognize the target is calculated. This calculation is dependent on target angular size in degrees, received contrast in percent, and clutter. The mean time to recognition is then converted into an expected number of scan intervals to recognize. The remaining steps in the calculation mimic those used in calculating the detection probability.
The asymptotic probability, P_∞, is compared with a cumulative probability P_c of recognition up to the current time (Statement 118). The routine

exits if P_c is already as large as P_∞. If not, the delta probability of recognition is calculated via equation (1) and the result is added to the cumulative probability of recognition. The new cumulative probability is placed in its proper place in the RECG array and is compared with the random number that was drawn at the time that detection had occurred. If P_c is now greater than that random number, recognition has occurred and the target is placed on the observer's recognition list (M14) and removed from the M13 list (Statement 119).

IMADET

Purpose: The purpose of this routine is twofold:

(1) To calculate the mean time to detection for an Image Intensifier device when the target is in the device field of view and when the target is not yet detected.

(2) To calculate two of the parameters needed for ascertaining the mean time to recognize when the target is already detected. The parameters calculated for this case are received contrast in percent and the angular subtense of the displayed target in degrees.

Arguments: IIDN (device seeker type), ITGT1, IXT1, IYT1 (potential target unit number and location coordinates respectively), IRG (square of distance to target in grid units), IDT (a return parameter).

Called by: SURV

The routine first calculates the received contrast on the display as a function of target-to-background intrinsic contrast, atmospheric attenuation and device transmission.

The intrinsic contrast, C_o, is calculated as follows

$$C_o = \left| \frac{M_2 - M_1}{M_1} \right|$$

where C_o is intrinsic contrast

M_1 = Image Intensifier background reflectance as developed from input conditions in the preprocessor. (Function of concealment index; also see Input Form 38).

M_2 = Image Intensifier target reflectance as developed from input conditions in the preprocessor. (See Input Form 39)

The received contrast, C, is then

$$C = \frac{C_o}{1 + \dfrac{K_3 \; P_2}{C_G \; TM_1}}$$

where $K_3 = 1 - e^{-\sigma_s R}$ (scattered component)

$C_G = \frac{1}{2}(1+Rg)$ (sky-ground ratio)

$T = e^{-(\sigma_s + \sigma_a)R}$ (atmospheric transmittance)

$P_2 = \frac{1}{e_c} \int_{0.4}^{0.9} B(\lambda)Q(\lambda) \, d\lambda$ (flux density)

R_g = the reflectance of the ground

σ_s = atmospheric scattering coefficient

σ_a = atmospheric absorption coefficient

R = range to target in meters

$B(\lambda)$ = spectral radiance of the night sky in $\frac{\text{watts}}{\text{cm}^2 - \text{steradian-micron}}$

$Q(\lambda)$ = spectral sensitivity of the photocathode in amperes/watt

e_c = electron charge in coulombs

After the received contrast, C, is calculated, it is multiplied by 100 to get percent received contrast (RECCON) and is retained as one of the parameters to enter the search equation.

Next the angle, Θ_T, (in degrees) that is subtended by the displayed target is calculated.

$$\Theta_T = \left(\sqrt{\frac{A}{A_o}}\right) \frac{W_T}{R} \cdot M \cdot \frac{180}{\pi}$$

where M is the device magnification

W_T is the target width in meters when in open terrain

R is the range to target in meters

A is the exposed target cross section after taking concealment into account

A_o is the fully exposed target cross section.

After Θ_T and C are calculated, the next step is to determine whether or not the seeker has already detected this target. If so, further calculations will be made to determine if he will now recognize the target. To this end control goes to statement 120.

If it is determined that this target is not detected yet, control goes to statement 1200. Here, the remaining parameters needed for the search equation are calculated. They are the display luminance, B, the angular subtense of the display, Θ_D, and the threshold contrast, C_T.

The display luminance, B, (in foot-Lamberts) is given by

$$B = .093\ GA$$

where G is the light-flux gain of the Image Intensifier device in $\frac{\text{foot-Lamberts}}{\text{foot-candle}}$

(an input value: $G \sim 3.5 \times 10^5$)

and

$$A = \frac{10^4 \pi \gamma}{4(f_n)^2} \int_{0.4}^{0.9} B_\lambda K_\lambda R_{B\lambda} d\lambda \quad \text{[A is in lumens/m}^2\text{.]}$$

$$= 7854 \frac{\gamma}{(f_n)^2} \int_{0.4}^{0.9} B_\lambda K_\lambda R_{b\lambda} d\lambda$$

where γ = device transmission (typical value = 0.92). (This is input on Form 37A, Cols. 63-64.)

f_n = image intensifier system f-number. (This is input on Form 37A, Cols. 9-11; typical value is 1.6.)

K_λ = photopic luminosity curve in lumens/watt. This is a function of the wavelength, λ. It does not change with changes in night sky brightness and so can be hard-wired into the battle model. Its values are:

λ (in microns)	K_λ
.40	0.27
.45	25.84
.50	219.64
.55	676.60
.60	429.08
.65	72.76
.70	2.79
.75	0.08
.80	0.01
.85	0.00
.90	0.00

B_λ = night sky brightness in watts/(cm^2)(μ)(Ω). This is in the form

$$B_\lambda = 10^{(a\lambda + b)}$$

and the values a and b are dependent on Input Form 40 (Environmental Data Form). Form 40 gives one of three conditions:

Starlight, Part Moon, or Moonlight

which then points to the corresponding equation for B_λ in the First Preprocessor.*

$R_{B\lambda}$ = background reflectance and is a function of λ and of the concealment index of the square occupied by the target.

The angular subtense of the display, Θ_D in degrees, is calculated by multiplying the device magnification by the field of view in degrees.

Threshold contrast on the display, C_T, is determined by interpolation. Using Θ_T in minutes and B in ft-Lamberts as arguments, the function CONTST is referenced to provide the interpolated C_T. The value C_T and the received contrast, C, are used to calculate X by

$$X = \frac{C - C_T}{0.48\ C_T}$$

Finally the search algorithm is used to provide the mean time to detect a target that is in the device field of view (in the absence of clutter which is considered later in the routine DETREC). The search algorithm is:

$$\tau = 0.52 + \frac{.016}{\Phi(X)} \left[\frac{\Theta_D^{\ 2}}{\Theta_T^{\ 3} C^2 B^{0.55}} \right]$$

where τ is the mean time to detect in seconds, Θ_T, C, Θ_D and B are developed in previous steps and $\Phi(X)$ is a normal probability integral. $\Phi(X)$ is a new function in the Battle Model with X as input argument. (The new function is named PHIX.)

After the mean time, τ, to detect is calculated, the subroutine DETREC is called (at statement 120) to determine the overall time to detect this target and to determine whether it is detected at this scan interval.

If it was determined earlier that this target was detected but not recognized then control was transferred to statement 120 where the subroutine DETREC is called to determine whether recognition will now occur.

LSCHEK

Purpose: The purpose of the LSCHEK subroutine is fourfold:

(1) to determine if intervisibility (or line of sight) exists between the unit being processed and each combat units on the opposite side,

(2) to determine which intervisibile enemy combat units are also in the search sector of the unit being processed,

(3) to determine which intervisibile enemy combat units have search sectors that encompass the unit being processed,

(4) to initiate and terminate the stored random number (for the appropriate unit) against which the cumulative probability of detection/recognition is compared periodically during the time of continuous intervisibility.

Arguments: Labeled common MAIN, CNTRL, DIAGTL

Called by: BDMONT, BMOUNT, BOUNDX, CHGVRT, MOVE, NEWMIS.

After unpacking the coordinates and altitudes of all enemy combat units, and the search sector bounding angles of the combat unit being processed, the COVME subroutine is called to construct the new intervisibility coefficients for the unit.

Within the DO 30 loop, the LOS function is checked to determine if line of sight exists to each enemy combat unit.

For those enemy units that are not in line of sight, control goes to statement 26 where the appropriate bits in the SECH array are zeroed. This includes the bit corresponding to the enemy unit in the array of the unit being processed and the bit corresponding to the latter in the array of the former. Also the appropriate cumulative probabilities of detection/recognition with the associated random number located in the RECG array are set to zero for the processed unit with respect to the enemy unit and vice-versa.

For those enemy units that are intervisible with the unit being processed, the following is done (statement 20). After setting the logical array LLOS, the SECH array is checked to see if the enemy unit was already in the search sector of and in line of sight of the unit being processed. The word IBJ is set to one if this were the case and to zero if not. Then the AOS subroutine is called to determine if the enemy unit is now in the unit's search sector. If so the word IBB is set to one and if not the word is zeroed. If both words IBJ and IBB are equal to one, signifiying that the enemy continues to be intervisible with and in the search sector of the unit being processed, control goes to statement 24. However, if one word (either IBJ or IBB) is equal to one while the other is zero, it means the enemy has either (1) just come into line of sight and search sector or (2) just gone out of line of sight and search of the unit. In either case, a change is made in the unit's RECG array; if, on the one hand, the enemy has just disappeared, then the appropriate cumulative probability and random number concerning the enemy unit are both zeroed; if, on the other hand, the enemy has just come into the combination of search sector and line of sight of the unit being processed, then a new random number is entered into the RECG array for later comparison with an accumulating probability of detection for the unit.

Control then goes to statement 24 (still within the DO 30 loop) where a corresponding evaluation of the enemy unit search sector is made to determine if the unit being processed is now in the enemy unit search sector and if it was before. If the enemy unit search sector contains the unit being processed now and did before (i.e., if IBB and IBK are both non-zero) then control goes to statement 30 for evaluation of the next enemy unit within the DO 30 loop. If IBB is non-zero and IBK is zero, signifying that the unit being processed has just entered the enemy unit's search sector, then a new random number is placed in the appropriate position of the enemy unit RECG array. If IBB is zero and IBK is non-zero, signifying that the unit has just left the enemy unit search sector, then the appropriate position of the enemy unit's RECG array is zeroed.

The DO 60 loop calls SEEU and sets the appropriate line of sight bit ON or OFF in the eleventh control word of the enemy unit. The bit pattern for the unit being processed is then packed in its eleventh control word.

PCTSEE

Purpose: To determine how much land along a terrain profile is visible from an observer position at one end of the profile.

Arguments: JXS, JYS, JHS, PSI (coordinates and height or altitude of observer and direction of profile from him), labeled common MAIN, TERRAN

Called by: COVME

This subroutine checks each terrain square along a profile in the direction of PSI (starting with the location of the observer) to determine which squares are visible to the observer (i.e., not masked by intervening terrain and/or vegetation). The profile is extended 3000 meters from the observer and segmented into 500 meter increments. Along each increment, the fraction of land that is visible to the observer is collected and retained for calculations in the subroutine COVME. For the significance of this calculation, see the description of the subroutine COVME.

PHIX (Function)

Purpose: To provide the probability integral from minus infinity to X of the normal or gaussian distribution.

Argument: X

Called by: IMADET, THERM

The PHIX function approximates the probability integral of the normal distribution. For value x = 0.2, 0.4, 0.6, . . ., 3.0, the function gives answers corresponding to stored data values. For values of x that are between the stored data points, a linear interpolation is employed to provide the answer. For values of x greater than 3.0, PHIX is set to 1.0. For values of x less than - 3.0, PHIX is set to PHIX (-3.0) or 0.0014. For values between -3.0 and 0, PHIX(X) is set to 1.0-PHIX(-X).

SURV

Purpose: The surveillance subroutine is the basis for generating intelligence for command units and weapon units. It is called each scan cycle for each sensor class and type. It sets up the calls to IMADET, THERM, and TGTACQ and calls COMMO if new detections (MI3 information) occur.

Arguments: Labeled common MAIN, CNTRL, SURVEL.

Called by: EXEC 2.

The subroutine first checks the pinned down status of the unit since a unit that is pinned down will lose all intelligence except nearest square. All intelligence, MI2, 3 and 4 for the unit being processed are set to FALSE (DO 5). If a command (headquarters) unit is being processed the sensor class and type are extracted from JCMD. If its buddy unit is busy a random number is checked as the command unit then has only a 50% chance of going through surveillance. If the random number is smaller than this chance the detections are set to zero.

If the buddy unit is not busy or if the random number permits the command unit to go through surveillance, MI2 and known dead are set. Control then goes to statement 20.

If a weapon unit is being processed MI2 and known dead are set, and if the unit is not pinned down, MI3 and MI4 are set (DO 3). The line of sight and all weapon event clocks and codes are extracted.

Location of all enemy units is then extracted for both command and weapon units. The probability of loss of information for the sensor is entered into LTI. If the sensor class if 5 or 6, skip is to call TGTACQ (statement 140).

If a weapon unit is being processed, the recognized targets (MI4) that it already has are counted and if that number is 2 or more, control is transferred to TGTACQ (statement 140) thereby skipping new acquisitions for sensor classes 2 and 3.

For all remaining weapon units and command units new acquisitions are now possible. Each enemy unit that is both in line of sight and search sector is processed (statement 50) for possible gain of information within the DO 100 loop. Those enemy failing this test are removed from the MI3 and MI4 lists of the weapon unit seeker and MI2 is probabilistically removed (by comparing LTI against a random number) from the seeker list be he weapon or command unit (statements 46 and 80). For each enemy in LOS and search sector (statement 50) and on whom information is not complete, subroutines are called by seeker class to determine information improvement. Respectively, sensor classes 1, 2, 3 and 4 are processed by calls to VISDET (at statement 52), IMADET (at statement 53), THERM (at Statement 54) and RADAR (at statement 55). For calls to IMADET and THERM, a switching mechanism is employed to provide a recall to the respective subroutine whenever detection (MI3) is achieved by the first such call. The second call then initiates the achievement of recognition on this target. (Thus both detection and recognition can occur at the same time.) Before the second call to the appropriate subroutine (at the time detection has occurred) the RECG array is modified (at statement 57) to zero the cumulative probability of detection/recognition and to provide a new random number against which the subsequently-growing probability of recognition will be repeatedly compared (at the end of each scan interval).

The calls to VISDET and RADAR retain the rules that they operated under with previous versions of CARMONETTE; they attain state 2 (MI3) information via these calls (to VISDET and RADAR) and then rely on the MARKOV process within the TGTACQ routine to achieve MI3 and MI4 information. On the other hand, calls to IMADET and THERM achieve MI3 and MI4 information (for seeking weapon units) by calls to those two subroutines and rely on the TGTACQ routine for only "death of target" information.

Command units seeking within the DO 100 loop can acquire only MI2 information (to be communicated to weapon units) no matter which sensor class they are employing. Thus a command unit employing sensor class 2 achieves MI2 information via a call to IMADET by the same rule structure that the corresponding weapon unit would achieve MI3 information.

After all enemy units have been processed within the DO 100 loop, control is transferred to TGTACQ (statement 100).

After return from target acquisition known dead, MI2, MI3, and MI4 information is assembled for transfer into JINTEL, the sensor clock and code are packed, the communications subroutine is called if switch was set in TGTACQ, and control is returned to EXEC2.

THERM

Purpose: The purpose of this routine is twofold:

(1) to calculate the mean time to detection for a hermal device when the target is in the device field of view and when the target is not yet detected,

(2) to calculate two of the parameters needed for ascertaining the mean time to recognize when the target is already detected. The parameters calculated for this case are received contrast in percent and the angular subtense of the displayed target in degrees.

Argument: IST (device seeker type), ITARG, IXT1, IYT1 (potential target unit number and location coordinates, respectively), IRNG (square of distance to target in grid units), IDT (a return parameter).

Called by: SURV.

The routine first calculates two parameters that will be used by DETREC to determine mean time to detection or recognition. These two parameters are display contrast, C (in percent), and the angle Θ_T (in degrees), that is subtended by the displayed target.

Display contrast, C , in percent is calculated as follows:[1]

$$C = (SNRV) \cdot (NE\Delta T) \cdot C_S \cdot 100 \qquad (1)$$

$$(SNRV) \cdot (NE\Delta T) = \tau_e \cdot A \cdot (TF)_h (TF)_v \; e_T \Delta T + (e_T - e_B) T_B / 4$$

where (SNRV) = signal-to-noise ratio, video

(NEΔT) = noise equivalent temperature difference

τ_e = effective atmosphere/optics transmittance

$(TF)_{h,v}$ = amplitude response function; horizontal, vertical

[1] Private communication from Texas Instruments, Dallas.

A = fraction of target cross-sectional area if less than resolution element area

e_T = mean target emittance

e_B = mean background emittance

ΔT = temperature difference between target and background in degrees Celcius

T_B = background temperature of battlefield in degrees Kelvin

C_S = contrast at display saturation.

$\tau_e = \tau_o e^{-(.00036RH_o)}$ (attenuation is a practical fit to available data)

H_o = amount of preciptable water (units of cm) in a horizontal column of atmosphere of 1 km in length (calculated in pre-processor from input temp. and humidity)

τ_o = a system parameter of the device

R = range to target in meters

The angle, Θ_T, subtended by the displayed target is calculated as follows:

$$\Theta_T = \frac{WTD + HTD}{2\ d_D} \left(\frac{180^o}{\pi}\right)$$

where

$$WTD = \frac{W_T}{R} \cdot \frac{D_H}{(FOV)_{AZ}} \cdot \frac{180}{\pi}$$

$$HTD = \frac{H_T}{R} \cdot \frac{D_V}{(FOV)_{EL}} \cdot \frac{180}{\pi}$$

$(FOV)_{AZ}$ = device field-of-view, azimuth (degrees)

$(FOV)_{EL}$ = device field-of-view, elevation (degrees)

W_T = target width in meters

H_T = target height in meters

R = range to target in meters

$D_{H,V}$ = display dimensions, horizontal and vertical in meters

d_D = viewing distance in meters such that display subtends about 18^o.

After C_s and Θ_T are calculated, it is determined whether or not the seeker has already detected this target. If so, further calculations will be made to determine if he will now recognize the target. To this end control goes to statement 120.

If it is determined that this target is not yet detected, control goes to statement 1200. At that point, the remaining parameters needed for the search equation are calculated. They are the angular subtense of the display, Θ_D, the display luminance, B, and the threshold contrast, C_T.

The angular subtense of the display, Θ_D in degrees, is calculated by:

$$\Theta_D = M \sqrt{(FOV)_{AZ}\ (FOV)_{EL}}$$

where $(FOV)_{AZ}$ = horizontal field-of-view of device in degrees

$(FOV)_{EL}$ = vertical field-of-view of device in degrees

M = device magnification

The display luminance, B, for the thermal device is represented here as a constant at 10 ft-Lamberts since it is easily adjusted.

Threshold contrast, C_T, is determined by interpolation within the CONTST function (with arguments Θ_T in minutes of arc and B in ft-Lamberts). C_T is then used along with the received contrast, C , to calculate X where

$$X = \frac{C - C_T}{0.48\ C_T} .$$

Finally the search algorithm is used to provide the mean time to detect a target that is in the devise field-of-view (in the absense of clutter which is incorporated later in the routine DETREC. The search algorithm is

$$\tau = 0.52 + \frac{0.016}{\Phi(X)} \left[\frac{\Theta_D^{\ 2}}{\Theta_T^{\ 3} C^2 B^{0.55}} \right]$$

where τ is the mean time to detect in seconds, and Θ_T, C, Θ_D, and B are developed in previous steps and $\Phi(X)$ is a normal probability integral. $\Phi(X)$ is a new function in the Battle Model with X as input parameter (the new function is labeled PHIX).

After the mean time, τ, to detect is calculated, the subroutine DETREC is called (at statement 120) to determine the overall time to detect this target and to determine whether it is detected at this time (Monte Carlo decision).

If it was determined earlier that this target was detected but not recognized then control was transferred to statement 120 where the subroutine DETREC is called to determine whether recognition now will occur.

TGTACQ

Purpose: The target acquisition subroutine degrades or upgrades the intelligence states of information on all enemy units. These changes depend upon the detection probabilities for change of information depending on activity and movement of seeker, movement of target, and solid angle thresholds of sensor and range. If erroneous pinpoint information exists after processing, entrances to the communications and target select subroutines are set. For seeker classes 2 and 3 the target location information (MI2, MI3, MI4) changes of intervisible targets are bypassed since these are evaluated in other subroutines (IMADET and THERM).

Arguments: Labeled common MAIN, CNTRL, SURVEL, H''DAT.

Called by: SURV.

Enemy units known dead, mc,ing, and apparent radius for detection are unpacked. If the unit being processed is moving and can fire while moving, its weapons' which are not awaiting impact or assessment, and where clocks are not upper infinity, has the event clock set to lower infinity (DO 7). This will force the weapon into target select. The solid angle thresholds and detection probabilities are unpacked (DO 4). The intelligence on number of units known to NS, EPP, and PP upon entering this subroutine is stored in MI2, 3, 4B. If a weapon unit is being processed, PRORTG is called; this sets the MZ TRUE for enemy units on which surveillance is to be performed.

The DO 100 loop processes all enemy units for which MZ is TRUE. If the unit is not in line of sight and not known dead, all intelligence is degraded one level. If unit is known only to M12, a random number is checked to determine if all information is lost. If the unit is not on the MZ TRUE list and line of sight is lost, all intelligence on the unit is lost. If in line of sight, all units who are in range and who are not concealed are counted. In either case, all other intelligence is deleted if the enemy unit is known dead.

If MZ is TRUE and line of sight exists, control goes to statement 130. Here the number in line of sight is incremented and the range is calculated. If the unit is not concealed (apparent radius of detection from JUCHAR not equal to zero) units not concealed, NKON, is incremented. KONSA (the solid angle) is computed by squaring the apparent radius, scaled 2^6 and divided by the range. (Recall the range is in grids squared.)

The first index (MOVE) for the LPij arrays are set (see comments). The variable JANGLE is then selected by comparing KONSA with the solid angle thresholds. This is the second index for the LPij. If the target is dead, a check is made to determine if the unit now learns target is dead. If so all intelligence is removed and processing this target stops (statement 105).

At this point, if the seeker class is 2 or 3 control is transferred to statement 101 (History printouts) and processing of this target stops. Otherwise, if target is not known dead, processing continues by referencing IRN and moving the random number into NEWRN. This is multiplied by two if the observer is moving.

If the target is accurately pinpointed, control goes to 260 where it is taken off the PP and EPP list. NEWRN is checked against LP41 (losing all info). If less than, control goes to 230 and target is taken off NS list. If NEWRN is less than the sum of PP to NS and PP to no information, processing of this target is finished. If greater than or equal to, NEWRN is compared to the sum of PP to EPP and PP to no info, and if greater than or equal to, control goes to 210 where MI4, MI3, and MI2 are set TRUE. If less than, MI3 and MI2 are set TRUE. If a command unit and MI2 was TRUE, the corresponding bit in JCDET is turned ON.

If the target is erroneously pinpointed, control goes to statement 250 where MI3 is set FALSE. If NEWRN is set less than EPP to no info, control goes to 230. If greater than or equal to, is compared to the sum of EPP to NS and EPP to no info, if less than processing is completed.

If greater than or equal to, is compared with the sum of EPP to PP and EPP to NS, and EPP to no info; if less than, target is added to EPP and PP list, if greater than or equal to, is added to EPP list.

If target is known to nearest square, control goes to 220. NEWRN is compared with NS to no info, if NEWRN is less than the NS to no info, the target is taken off the NS list. If NEWRN is greater than or equal to NS to no info, NEWRN is compared to the sum of NS to EPP and NS to no info. If NEWRN is less than this sum, the target is placed on the EPP and the NS list. If NEWRN is greater than or equal to this sum, NEWRN is compared to NS to PP + NS to EPP + NS to no info. If NEWRN is greater than NS to PP + NS to EPP + NS to no info, processing of this unit is completed. If NEWRN is less than NS to PP + NS to EPP + NS to no info, the target is placed on the PP, the EPP, and the NS lists.

After exit from the DO 100 loop, control goes to statement 500 where the number of enemy units in each of the intelligence states are counted.

Then at DO 102 and statement 103, information for the three intelligence messages are stored for the history messages. At DO 802 if a weapon unit has any targets erroneously pinpointed, the switch, ICOMMO is set for the communications subroutine to be called from the surveillance subroutine. If no EPP information exist, control returns to calling routine.

If the unit being processed has a weapon able to fire, the first such weapon is set for call to target select, and control is returned to the surveillance routine.

3.13 NEW INPUT FORMATS

Additional input data were needed to incorporate the Zirkind search model. To this end, two input forms were added and several existing ones were modified. The bulk of the new input was needed for the introduction of thermal devices. For the image intensifier devices, most of the data that was needed were already formatted for the CARMONETTE IV and V Models. These formats were retained with only minor alterations. The introduction of a search sector for each combat unit required that this either be introduced on a totally new format or by the modification of an existing one. The latter course was selected and the "UNIT 3" format was modified to accommodate this inclusion.

The new and modified formats are presented and depicted next.

3.13.1 Form 37A1 - Image Intensifier Data

Form 37A1 - Image Intensifier Data, is one of the two forms used to input the characteristics of the image intensifier class of passive night vision devices used in the game. (The other form is numbered 37B.) Both are critical to target detection and recognition. The entries on Form 37A1 are for the most part self-explanatory, with the possible exception of the entry in col. 65-72. This is the optical or light flux gain, not the system gain. Its values characteristically range from 10^4 to 10^6.

3.13.2 Form 37A2 - Thermal Data

Form 37A2 - Thermal Data, is used to input the characteristics of the thermal class of optical devices into the game.

3.13.3 Form 37B - Image Intensifier Photocathode Sensitivity

The entries in columns 7 to 72 of Form 37B are the ordinate values of the curve of photocathode tube sensitivity (in amps/watt) at selected points along the abscissa of the curve. The abscissa (not given in the form) is in microns and the selected points along it must be eleven equally spaced values (λ_0 to λ_{10}). These same values of λ_0 to λ_{10} are used for determining the entries in Forms 38 and 39 for background and target reflectance.

FORM 37A1

IMAGE INTENSIFIER DATA

SENSOR CLASS (1)	SENSOR TYPE (2)	FIELD OF VIEW, DEGREES (3–5)	MAGNIFICATION (6–8)	OBJECTIVE F NUMBER (9–11)	OBJECTIVE FOCAL LENGTH, MILLIMETERS (12–14)	(15–62)	DEVICE TRANSMISSION (63–64)	OPTICAL GAIN IN FOOT-LAMBERTS PER FOOT CANDLE (65–72)	IDENTIFICATION: ID (73–76)	IDENTIFICATION: SEQ. NO. (77–80)
2	1								PNV1	
2	2								PNV1	
2	3								PNV1	
2	4								PNV1	
2	5								PNV1	
2	6								PNV1	

Fig. 7 - Example of Form 37A1

FORM 37A2

THERMAL DATA

SENSOR CLASS	SENSOR TYPE	HORIZONTAL FIELD OF VIEW, DEGREES	VERTICAL FIELD OF VIEW, DEGREES	MAGNIFICATION	WIDTH OF DISPLAY, METERS	HEIGHT OF DISPLAY, METERS	CONTRAST AT DISPLAY SATURATION	SYSTEM RESOLUTION, MILLIRADIANS	VIEWING DISTANCE, METERS	IMPULSE RESPONSE, MILLIRADIANS		DEVICE TRANSMISSION		IDENTIFICATION ID	IDENTIFICATION SEQ. NO.
1	2	3 4 5	6 7 8	9 10 11	12 13 14	15 16 17	18 19 20	21 22 23	24 25 26	27 28 29	30–62	63 64	65–72	73 74 75 76	77 78 79 80
3	1													P N V 1	
3	2													P N V 1	
3	3													P N V 1	
3	4													P N V 1	
3	5													P N V 1	
3	6													P N V 1	

Fig. 8 - Example of Form 37A2

Form 37B

IMAGE INTENSIFIER PHOTOCATHODE SENSITIVITY

SENSOR CLASS	SENSOR TYPE	PHOTO-CATHODE TYPE	ORDINATES OF PHOTOCATHODE SENSITIVITY, AMPS/WATT, Q(λ)											IDENTIFICATION	
			Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	ID	Seq. No.
1	2	3 4 5 6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60	61–66	67–72	73–76	77–80
2	1		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	
2	2		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	
2	3		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	
2	4		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	
2	5		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	
2	6		E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	E -	PNV2	

Fig. 9 - Example of Form 37B

3.13.4 Form 37C - P Infinity

Form 37C is used to input the limiting ranges in kilometers at which the image intensifiers and thermal devices can detect and recognize targets of various sizes and posture. At present this format is not configured to accept input for sensor classes other than the two mentioned.

3.13.5 Forms 38 and 39 - Background and Target Reflectance

Form 38 - Background, and Form 39 - Target, are used for the entries of spectral reflectance of the types of background and of targets played in the game. This data is used in generating the intrinsic contrast of target to background when image intensifiers are searching for targets. The values of λ_0 to λ_{10} (in microns) on each form at which the reflectance values are entered must be the same as the equivalent values used in preparing Form 37B.

On Form 38, the background numbers in columns 1 and 2 are equated to the values of the concealment index for the grid square as established in the preparation of terrain inputs. A determination must be made as to the type of background, i.e., sand, loam, grass, bushes, etc. to be related to the concealment indexes used.

On Form 39, the target classes are identified in columns 1 and 2 and correspond to the entries in columns 4 and 5 of the UNIT 3 format.

3.13.6 Form 40 - Environmental Data

Form 40 is used for entering the scattering and absorption coefficients of visible light (used by image intensifier algorithms). Air temperature, humidity, and background temperature (used by thermal device algorithms) are also entered on this form as is background emittance in two states. The first state of background emittance (cols. 29-32) corresponds to a terrain concealment index of 1 through 4 representing sparce vegetation. The second state (cols. 33-36) corresponds to a terrain concealment index of 5 through 16, representing relatively heavy vegetation.

FORM 37C

CARMONETTE

P INFINITY

(Ranges for asymptotic probabilities: Sensor Classes 2 & 3)

SENSOR CLASS	SENSOR TYPE	TARGET ELEMENT	SIZE INDEX	DETECTION								RECOGNITION									IDENTIFICATION	
				OPEN				DEFILADE				OPEN				DEFILADE					ID	SEQ. NO.
				R_{100}*	R_{75}	R_{50}	R_0	R_{100}	R_{75}	R_{50}	R_0	R_{100}	R_{75}	R_{50}	R_0	R_{100}	R_{75}	R_{50}	R_0			
1	2	3	4	5 6 7	8 9 10	11 12 13	14 15 16	17 18 19	20 21 22	23 24 25	26 27 28	29 30 31	32 33 34	35 36 37	38 39 40	41 42 43	44 45 46	47 48 49	50 51 52	53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76	77 78 79 80
																					P I N P	
																					P I N P	
																					P I N P	
																					P I N P	
																					P I N P	
																					P I N P	
																					P I N P	
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																					P I N P	
																					P I N P	
																					P I N P	
																					P I N P	

* R_n = range in kilometers at which P_∞ = n.

Fig. 10 – Example of Form 37C

* R_n = range in kilometers at which P ∞ = n. Fig. 10 - Example of Form 37C

FORM 38

BACKGROUND

BACKGROUND NUMBER	WAVELENGTH (microns) and BACKGROUND REFLECTANCE (percent)																						IDENTIFICATION	
	λ_0	%	λ_1	%	λ_2	%	λ_3	%	λ_4	%	λ_5	%	λ_6	%	λ_7	%	λ_8	%	λ_9	%	λ_{10}	%		ID	Seq. No.
01																								BKV1	
02																								BKV1	
03																								BKV1	
04																								BKV1	
05																								BKV1	
06																								BKV1	
07																								BKV1	
08																								BKV1	
09																								BKV1	
10																								BKV1	
11																								BKV1	
12																								BKV1	
13																								BKV1	
14																								BKV1	
15																								BKV1	
16																								BKV1	

Values fo . λ_{10} must be the same as the values of λ used as entry points on Form 37 for Photocathode $Q(\lambda)$

Fig. 11 - Example of Form 38

FORM 39

TARGET

TARGET CLASS	TARGET SIZE: LENGTH meters	WIDTH meters	HEIGHT meters	WAVELENGTH (microns) and TARGET REFLECTANCE (percent): λ_0	%	λ_1	%	λ_2	%	λ_3	%	λ_4	%	λ_5	%	λ_6	%	λ_7	%	λ_8	%	λ_9	%	λ_{10}	%	TARGET EMIT-TANCE, e_t	TEMP. DIFF.* (Celsius)	IDENTIFICATION: ID	Seq. No
1 2	3 4 5 6	7 8 9	10 11 12	13 14 15	16 17	18 19 20	21 22	23 24 25	26 27	28 29 30	31 32	33 34 35	36 37	38 39 40	41 42	43 44 45	46 47	48 49 50	51 52	53 54 55	56 57	58 59 60	61 62	63 64 65	66 67	68 69 70	71 72	73 74 75 76	77 78 79 80
01																												TGV1	
02																												TGV1	
03																												TGV1	
04																												TGV1	
05																												TGV1	
06																												TGV1	
07																												TGV1	
08																												TGV1	
09																												TGV1	
10																												TGV1	
11																												TGV1	
12																												TGV1	
13																												TGV1	
14																												TGV1	
15																												TGV1	
16																												TGV1	

* Mean difference in degrees Celsius between target and background.

Fig. 12 - Example of Form 39

FORM 40

ENVIRONMENTAL DATA

	CONDITIONS	VISIBLE LIGHT ATTENUATION COEFFICIENTS: SCATTERING σ_s	VISIBLE LIGHT ATTENUATION COEFFICIENTS: ABSORPTION σ_a		BACKGROUND EMITTANCE: STATE 1 (EB1)	BACKGROUND EMITTANCE: STATE 2 (EB2)	BACKGROUND TEMPERATURE, KELVIN	HUMIDITY, PERCENT	AIR TEMPERATURE, CELSIUS		IDENTIFICATION: ID	IDENTIFICATION: SEQ. NO.
1 2	3–11	12–18	19–25	26–28	29–32	33–36	37–40	41–44	45–48	49–72	73–76	77–80
11	STARLIGHT	E-	E-								COND	
12	MOONLIGHT	E-	E-								COND	
13	PART MOON	E-	E-								COND	

Fig. 13 - Example of Form 40

3.13.7 Form UNT3 - Blue and Red

Form UNT3, in columns 1 through 20, remains as it was previously. The modification to this form concerns columns 21 through 26 which are used to input the left (columns 21-23) and right (columns 24-26) bounds of each combat unit's search sector.

CARMONETTE

UNIT 3

UNIT DESCRIPTION - BLUE

Side	Unit No.	Target class	Vulnerability class	Fire size index	Mobility class	Fire response class	Sensor Class	Sensor Type	Max ran per vehicle	Fraction of time unavailable	Superior HQ		Left bound of search sector, degrees*	Right bound of search sector, degrees*	Identification ID	Identification Seq. No.
1	2 3	4 5	6 7	8	9	10	11	12	13 14	15 16	17 18	19 20	21 22 23	24 25 26	73 74 75 76	77 78 79 80
B	01														UNT3	
B	02														UNT3	
B	03														UNT3	
B	04														UNT3	
B	05														UNT3	
B	06														UNT3	
B	07														UNT3	
B	08														UNT3	
B	09														UNT3	
B	10														UNT3	
B	11														UNT3	
B	12														UNT3	
B	13														UNT3	
B	14														UNT3	
B	15														UNT3	
B	16														UNT3	
B	17														UNT3	
B	18														UNT3	
B	19														UNT3	
B	20														UNT3	
B	21														UNT3	
B	22														UNT3	
B	23														UNT3	
B	24														UNT3	

* East is 0°, North is 90°; West is 180°, South is 270°, etc.

Fig. 14 - Example of Form UNT3 - Blue

CARMONETTE

UNIT 3

UNIT DESCRIPTION - RED

Side	Unit No.	Target class	Vulnerability class	Eln size index	Mobility class	Fire response class	Sensor Class	Sensor Type	Max man per vehicle	Fraction of time unavailable	Superior HQ		Left bound of search sector, degrees*	Right bound of search sector, degrees*	Identification ID	Identification Seq. No.
R	01														UNT3	
R	02														UNT3	
R	03														UNT3	
R	04														UNT3	
R	05														UNT3	
R	06														UNT3	
R	07														UNT3	
R	08														UNT3	
R	09														UNT3	
P	10														UNT3	
R	11														UNT3	
R	12														UNT3	
R	13														UNT3	
R	14														UNT3	
R	15														UNT3	
R	16														UNT3	
R	17														UNT3	
R	18														UNT3	
R	19														UNT3	
R	20														UNT3	
R	21														UNT3	
R	22														UNT3	
R	23														UNT3	
R	24														UNT3	

* East is 0^{o}, North is 90^{o}; West is 180^{o}, South is 270^{o}, etc.

Fig. 15 - Example of Form UNT3 - Red

3.14 PREPROCESSOR MODIFICATIONS

Changes were made to both the first and second preprocessors.

3.14.1 First Preprocessor

The first preprocessor was altered where necessary to accept, organize, and transmit the additional data from the new and modified card input formats. The changes were made to three programs: DTREAD, NIGHTV, and FORM 4. No new programs, subroutines, nor functions were added to the first preprocessor.

In the program, DTREAD, modifications were made at statements 3860, 3940, 3962, 4000, and 4010. These additions to the program were made to read the new Thermal device data, optical gains for the Image Intensifiers, P_∞-values, target-background temperature differences, emittances of targets and backgrounds, and humidity and air temperature. Humidity and air temperature were then used to create a new parameter identifying the amount of water vapor per km. This parameter, entitled HO, is passed to the battle for use in determining the transmittance of thermal signals through the atmosphere. The subroutine DTREAD was also modified to pass to the battle model the following: the three target dimensions of each target class; objective F-number and field of view for each type of Image Intensifier.

In the program, NIGHTV, modifications were made to calculate the photo cathode display illuminance (in lumens/m^2) for the Image Intensifiers. For each of the six possible types of Image Intensifier in the game, the display illuminance is calculated as a function of the prevailing light level (starlight, moonlight, or partial moon), the 16 background reflectances, and the photopic luninosity curve. The equation and variables for this calculation are included in the description of the modified subroutine IMADET within the battle model.

In the program, FORM 4, modifications were made to store each combat unit's search sector bounding angles in the array IANG(48) for use in the second preprocessor and in the battle model.

3.14.2 Second Preprocessor

Changes were made to the second preprocessor to initialize the fractions of land visible to each combat unit for the six range intervals within his search sector. For this purpose, three subroutines, AOS, COVME, and PCTSEE from the battle model, were placed in the second preprocessor and the subroutine LSCHEK in the second preprocessor was modified to call the three new subroutines. Descriptions of the added subroutines, AOS, COVME and PCTSEE, are found in the section on battle model modifications.

The modifications to the LSCHEK subroutine in the second preprocessor are different from those to the LSCHEK subroutine in the battle model in the following way. In the battle model, LSCHEK places a new random number in the RECG array (detection probabilities and random numbers) whenever a potential target first appears intervisible with and in an observer's search sector. However, in the second preprocessor LSCHEK subroutine, no such modification to the RECG array occurs. Rather, all potential targets that are intervisible in a combat unit's search sector are placed in the SECH array* (as they are in the battle model). This initializes the battlefield geometry. Then the MAIN2X subroutine in the battle model (at the beginning of each new replication) initializes the RECG array with random numbers to correspond to the initialized information in the SECH array.

3.15 CARMONETTE PROGRAM AND DATA STORAGE REQUIREMENTS

At the end of Phase II, the CARMONETTE battle model storage requirement was 57,294 (or in octal, 157,716) words. The space available in either the CDC 6400 at UNA or the CDC 6600 at NVL is 98,304 (or 300K octal). Thus 58.3% of the total storage available is being used before we initiate the smoke model.

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*Performed in the AOS subroutine.